Information Circular 88-2

THIRTEENTH ANNUAL REVIEW OF ACTIVITIES

Project Résumés

1988

Edited by

Shasta A. Abbott

Minerals and Energy Division
Department of Natural Resources
and Energy
New Brunswick

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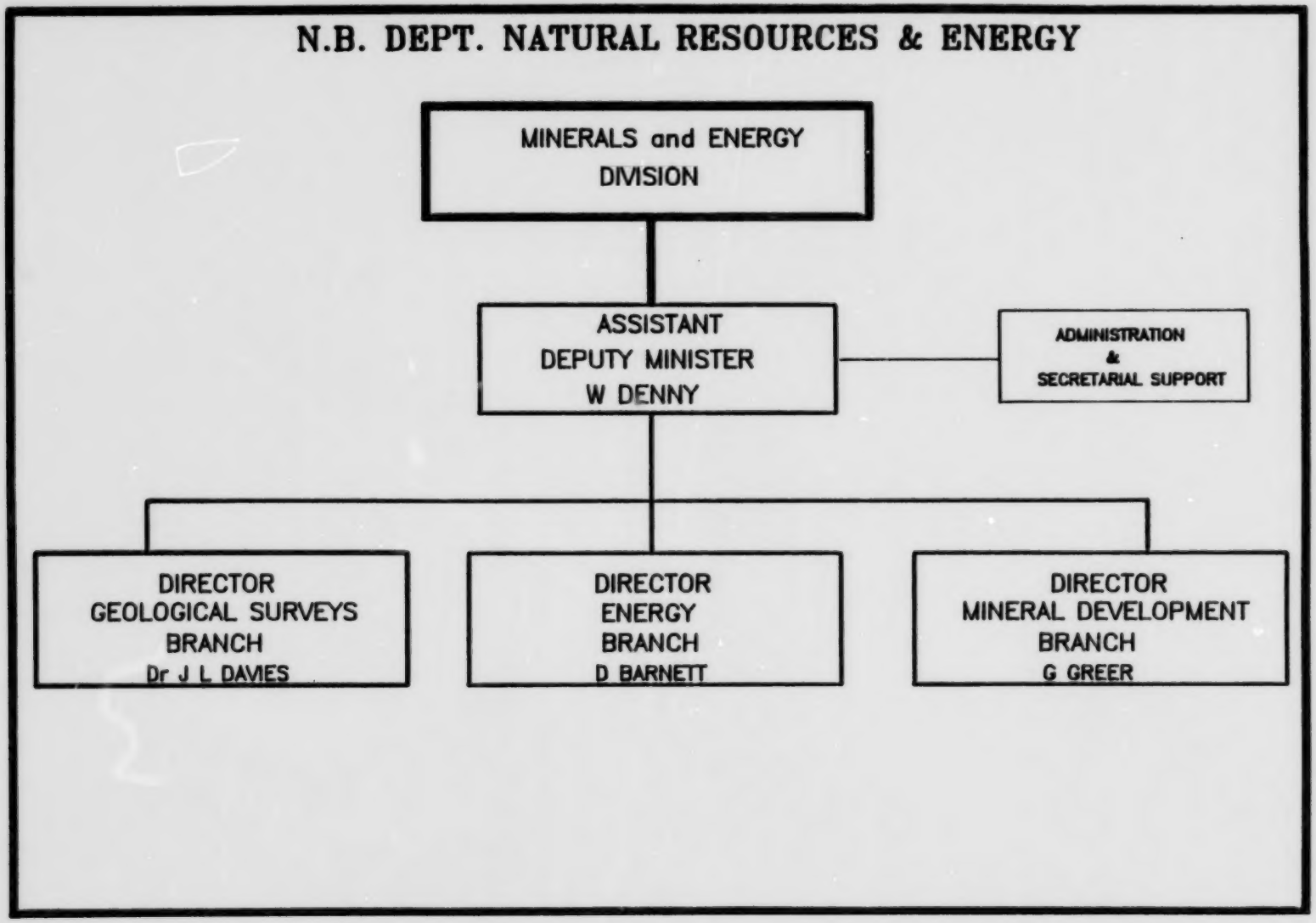
SECTION I

MINERALS AND ENERGY DIVISION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MINERALS AND ENERGY DIVISION

J.L. Davies

INTRODUCTION

The Minerals and Energy Division of the New Brunswick Department of Natural Resources and Energy is responsible for all mineral and energy resources owned and controlled by the Province. The Division administers, through a number of Acts, all matters related to exploration, development, production, smelting, refining, transportation, and taxation of metallic, nonmetallic, and structural mineral resources. The Division consists of the Geological Surveys Branch, the Mineral Development Branch, and the Energy Branch.

In past years, most of the geoscience activities were carried out by the Geological Surveys Branch with funds derived from the Canada-New Brunswick Mineral Development Agreement that expires March 31, 1989. The Provincial "A" budget, however, was given a substantial boost by Morris Green, who was appointed as Minister following the 1987 election of a new Liberal government. The increased funding will add three geoscientists to the Geological Surveys Branch staff and provide mineral exploration incentive programs in 1988-89.

GEOLOGICAL SURVEYS BRANCH (Director, J.L. Davies)

The Geological Surveys Branch is responsible for the collection and dissemination of information pertaining to the geology and mineral resources of New Brunswick. Closely associated activities include the encouragement of mineral exploration, promotion of the mineral industry, and providing assistance to government agencies who formulate resource and land-use policies.

MINERAL DEVELOPMENT BRANCH (Director, G.J. Greer)

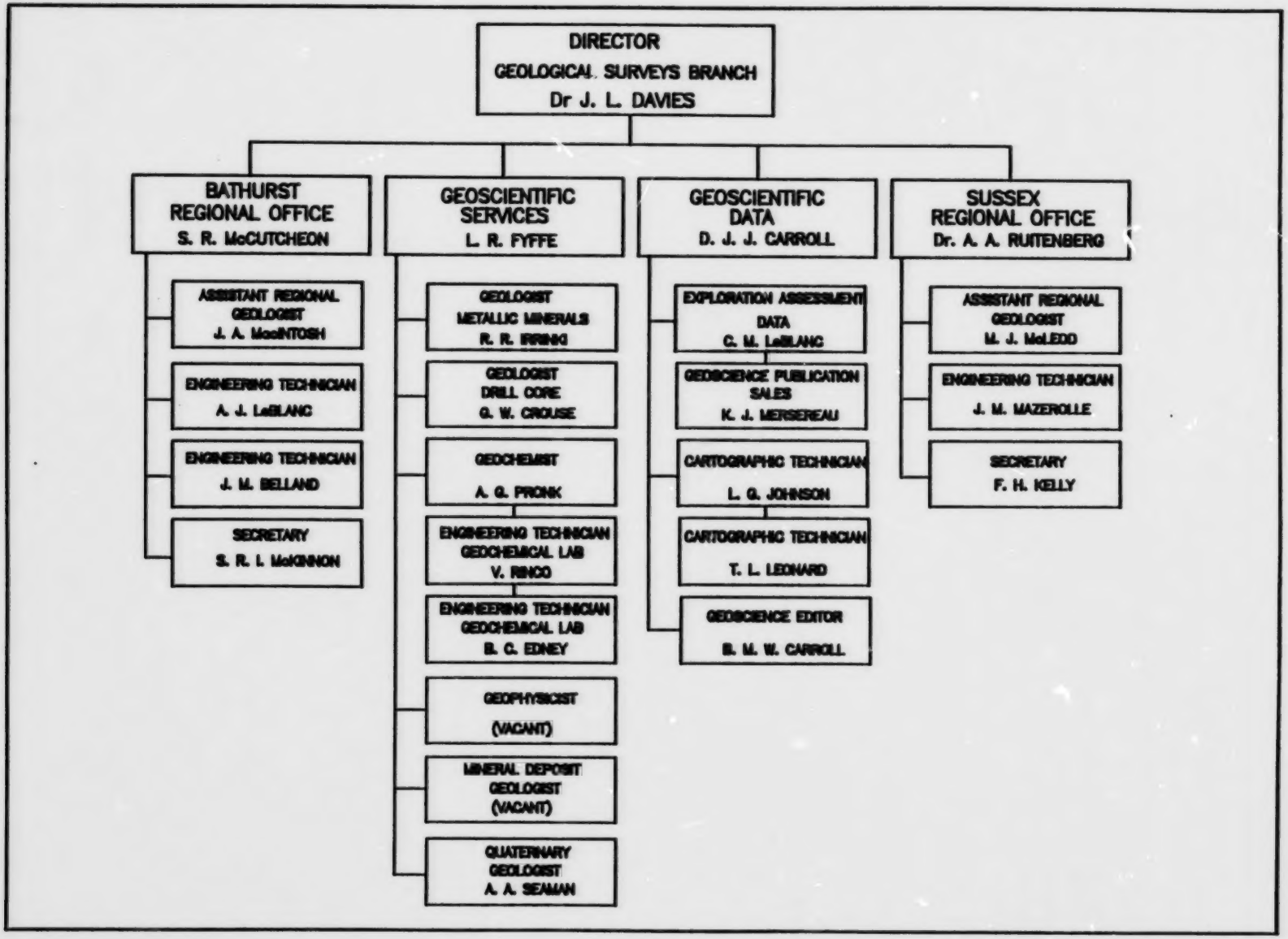
The Mineral Development Branch consists of four sections: Mineral Development, Mineral Processing, Mine Engineering, and Mineral Lands.

The overall goals of the Branch are: (1) to ensure that mineral deposits are developed at an optimum rate consistent with long-term income and employment objectives, (2) to enhance the economic viability of marginal mineral deposits, (3) to ensure that inactive or exhausted mines are rehabilitated to a state that avoids on-going costs to the public, (4) to ensure optimum recovery of minerals both in the mining and milling of the ores, and (5) to ensure the highest degree of in-province processing of mineral concentrates.

ENERGY BRANCH (Director, D.E. Barnett)

The Energy Branch has responsibility for all energy matters and, in this regard, is involved in a number of geoscience projects. These include assessment of coal, oil, gas, and oil shale resources by means of geological compilation of the Late Palaeozoic Maritimes Basin and the Early Mesozoic Fundy Basin. The oil shales of Albert County are being drilled and analysed to determine the beneficiation potential of the kerogen and/or carbonate minerals. A Mineral Development Agreement project is underway to study the sedimentology and diagenesis of the Stoney Creek oil and gas field near Moncton.

GEOLOGICAL SURVEYS BRANCH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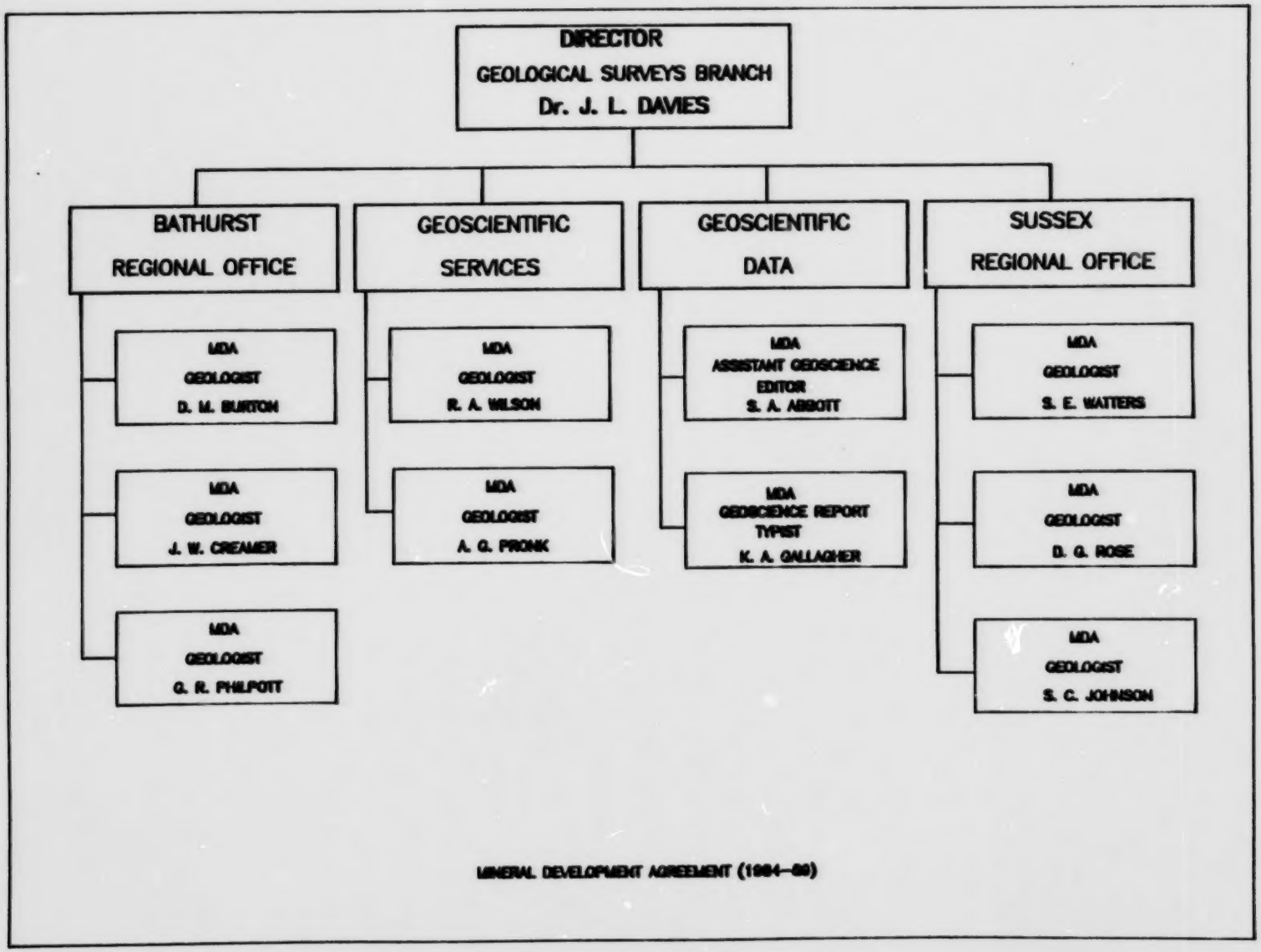

MINERAL DEVELOPMENT AGREEMENT (1984–89)

BATHURST REGIONAL OFFICE

ACTIVITIES OF THE BATHURST REGIONAL OFFICE

S.R. McCutcheon, Regional Geologist

The staff of the Bathurst Regional Office consists of Steven McCutcheon (Regional Geologist), James A. MacIntosh (Assistant Regional Geologist), Sharon McKinnon (Administrative Services Officer), and André LeBlanc and Maurice Belland (Engineering Technicians). D.M. Burton and G.R. Philpott, contract geologists responsible for projects funded through the Canada-New Brunswick Mineral Development Agreement (MDA), have both left the Department, and taken positions with NovaGold Resources and the American Academy of Dramatic Arts, respectively. J. Walker and A. Brewer will finalize their projects.

CANADA-NEW BRUNSWICK MDA PROJECTS

D. Baird and J. Walker finished the mapping and lithogeochemical sampling program in the Upsalquitch Forks (21 O/10) map area (p. 4). Nine of the twenty-five 1:10 000 maps were completed; the other sixteen were done last year by J. Creamer and B. Murphy (Burton et al. 1987). B. Murphy, who is doing an MSc thesis on the mafic intrusive and volcanic rocks in the area under the supervision of S. Barr at Acadia University, collected some additional samples for whole-rock geochemistry. The Upsalquitch Forks project was undertaken to locate favourable alteration zones, test them for their gold potential, and ascertain their geological setting.

G.R. Philpott prepared 1:20 000 geology maps of the Charlo River area (parts of 21 O/15 and 21 O/16) and did a petrographic and geochemical study of the intrusive rocks contained therein (p. 10). Samples have been submitted for analysis from the Popelogan porphyry-copper skarn to test for its gold potential. A final report on the project is being prepared.

The 1:10 000 geoscience compilation maps for NTS 21 O/8 are complete except for the geology layer. Compilation of the geology is in progress (p. 27).

The Heath Steele project, directed by P.L. Williams and A.L. McAllister, is in its final year. A progress report on the program appears on p. 22.

C. van Staal and his crew continued their structural-stratigraphic studies in the northern Miramichi and Elmtree terranes. They used the Bathurst office as their field base, utilizing some of its space and facilities.

PROVINCIAL PROJECTS

S.R. McCutcheon, D. Baird, and J. Walker relogged several of the drill holes at Lacana's (now Corona Corporation) Rocky Brook property in the Siluro-Devonian volcanic belt (21 O/9). The stratigraphic section is cut by a number of northerly dipping dykes of intermediate to felsic composition. Some dykes, particularly the felsic ones, are associated with brecciated, silicified, and mineralized fracture zones. An associated gravity anomaly suggests that these dykes and fractures may be coeval with a large intrusive body at depth.

S.R. McCutcheon and M.J. Belland sampled a suite of rocks at the BMS #6 open pit to determine if anomalous arsenic, antimony, mercury, +/- tin +/- bismuth +/- gold, are related to late, cross-cutting structures and if the quartz-porphyritic felsic tuffs that are associated with the "ore horizon" are actually epiclastic rocks.

Jim MacIntosh began geological mapping of Sugarloaf Provincial Park. The purpose of the project is; 1) to produce a layman's report on the geologic features of the park for distribution to tourists and, 2) to determine if the gold-in-till anomaly within the park is explained by the local geology.

R.R. Irrinki (Fredericton Office) and S. Creamer have been working on the Halfmile Lake sulphide deposit. S. Creamer has relogged and sampled many drill holes and all the information has been entered into a computerized file.

Diamond-Drill Core: In 1988, Acadia Mineral Ventures turned in over 6 000 m of core from various properties in the Millsteam area, and about 3 000 m of core was salvaged from the Popelogan deposit. Outside storage racks are being built at Madran that will accommodate about 100 000 m of core when complete. There is about this much core on the ground now.

OTHER ACTIVITIES

An electron-microprobe study was completed by L. Lewczuk from RPC on three gold-bearing samples from the Millstream area. The gold occurs as electrum (10-30% Ag) within pyrite and arsenopyrite, or at pyrite-arsenopyrite grain boundaries. The average electrum grain size is about 10 microns. Ankerite and Fe-rich chlorite are spatially associated with the gold. One sample contains adularia, a mineral that is associated with the "precious-metal horizon" in classic epithermal deposits.

Whole-rock chemical analyses were done on two massive sulphide samples adjacent to a felsic dyke, in the Brunswick #12 mine. Besides base metals, the rocks also contain up to 1700 ppb Au, 1000 ppm Sb, 300 ppm Sn, 20 ppm In, 440 ppm Cd, 1100 ppm Ag, and greater than 1000 ppb Hg.

The recent October 24th release shows the importance of airborne gradiometer data in delineating major geologic structures. The total magnetic field and vertical gradient maps for the Nepisiguit Lakes map sheet (NTS 21 O/7) show an elliptical structure that is centred upon the headwaters of the Tobique and Nepisiguit rivers. This structure, which measures 5 by 8 km, is also marked by a gravity anomaly and a topographic low. This evidence, together with the rock-unit distribution on the 1:250 000 geology map of New Brunswick (NR-3), indicates that this structure is an Early Devonian caldera complex. Abundant sedimentary rocks in its interior suggest that this caldera, the Mount Sagamook complex, is less deeply eroded than the Mount Pleasant caldera complex, and therefore has potential for intracaldera-, as well as ring-fracture-type deposits.

A field trip guide was prepared for the Gold Symposium that was held in Saint John in June. The same guide was used for the CIM District I field trip in September.

A portable radio-navigation unit, a LORAN CAPRI SCOUT, was tested for its accuracy in locating mineral occurrences. Precise locations are required for the New Brunswick Mineral Occurrence File. Unfortunately, this unit did not provide the required accuracy, but it is hoped that a satellite-based portable unit will prove acceptable.

D.M. Burton presented poster displays at the Prospectors and Developers in Toronto, the Atlantic Geoscience Society (AGS) meeting in Antigonish, and the Geological Association of Canada (GAC/MAC) meeting in St. John's, and gave a talk at the Gold Symposium in Saint John on the precious-metal potential of the Siluro-Devonian volcanic rocks in the Jacquet River belt. G.R. Philpott gave a talk at the CIM District 1 Meeting in Fredericton on the precious-metal potential of the Charlo River area. S.R. McCutcheon gave talks at the AGS and GAC/MAC meetings based on his thesis research on the Mount Pleasant caldera complex. He also gave a talk on epithermal mineralization at the District 1 meeting and participated in the G.S.A. Penrose Conference on marine evaporites in Windsor, Ontario.

S. McKinnon and A. LeBlanc provided their usual efficient service with regard to claim staking and recording. M. Belland monitored forestry operations for potential conflicts with mineral exploration.

GEOLOGY AND GOLD OCCURRENCES OF THE UPSALQUITCH FORKS MAP AREA (NTS 21 O/10)

J. Walker, D. Baird, and S. McCutcheon - MDA project

The Upsalquitch Forks area is located about 80 km west of Bathurst (Figure 1). In 1987, a project was begun by the New Brunswick Department of Natural Resources and Energy (NBDNRE) to map this area at a scale of 1:10 000 on newly released and updated digitized base maps. By the end of the 1987 field season, sixteen of the twenty-five maps had been completed (Burton et al. 1987). This year, field work on the remaining nine maps was concluded (Figure 2), and all twenty-five are now being compiled and integrated with the previous 1/4 mile geology maps.

GEOLOGY

The rocks in the Upsalquitch Forks map area range in age from Cambro-Ordovician to Upper Devonian. Highly deformed Cambro-Ordovician rocks of the Miramichi Zone (Tetagouche Group) are found in the southeast corner of the map area (M on inset map in Figure 3). Siluro-Devonian rocks of the Tobique-Chaleur Zone, which contain all of the recently discovered gold occurrences, are divisible into two parts. The southern part (TCs on inset map in Figure 3) is dominated by sedimentary rocks with minor volcanics to the west. The northern volcanic-dominated part (TCn on inset map in Figure 3) forms a wedge that begins in the southwest and widens to the northeast. Upper Ordovician to Lower Silurian rocks of the Aroostook-Matapedia Zone (AM on inset map in Figure 3) occupy the northwest part of the map area.

The entire area is cut by numerous faults trending east-northeast, the major one being the Rocky Brook-Millstream Break. In addition, small- to intermediate-sized mafic and felsic intrusions cut the stratigraphy.

MINERALIZATION

Most of the gold occurrences in the map area are spatially associated with intrusions. Different styles of gold mineralization largely reflect the level of intrusion-emplacement in the stratigraphic pile. Three broad subdivisions can be made, based upon increasing depth, as follows: 1) volcanic-hosted systems, 2) intrusion-hosted vein and/or breccia systems, and 3) skarn-type systems.

1. There is no known volcanic-hosted deposit within the map area, but the Rocky Brook deposit is located just east of the map boundary. Interbedded sedimentary rocks, which comprise only a minor part of the total section, are also mineralized. Cross-cutting, northwest-dipping, fracture zones with associated

1.

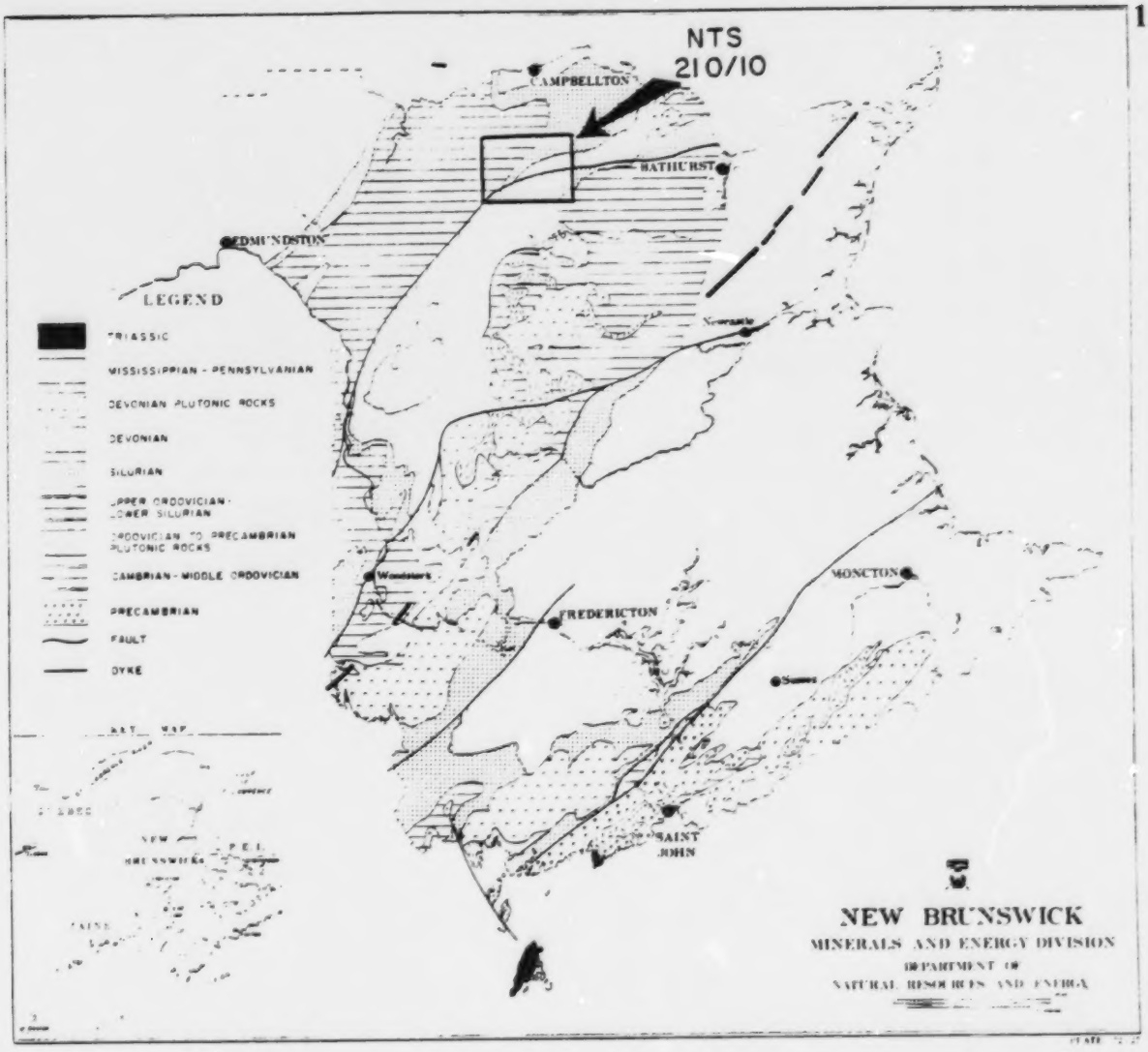

FIGURE 1. Geological map of New Brunswick showing location of Upsalquitch Forks map area (NTS 21 O/10).

2.

501	502	503	504	505
401	402	403	404	405
301	302	303	304	305
201	202	203	204	205
101	102	103	104	105

FIGURE 2. 1:10 000 scale index showing map coverage of NTS 21 O/10 during 1988. Shaded area represents 1987 work.

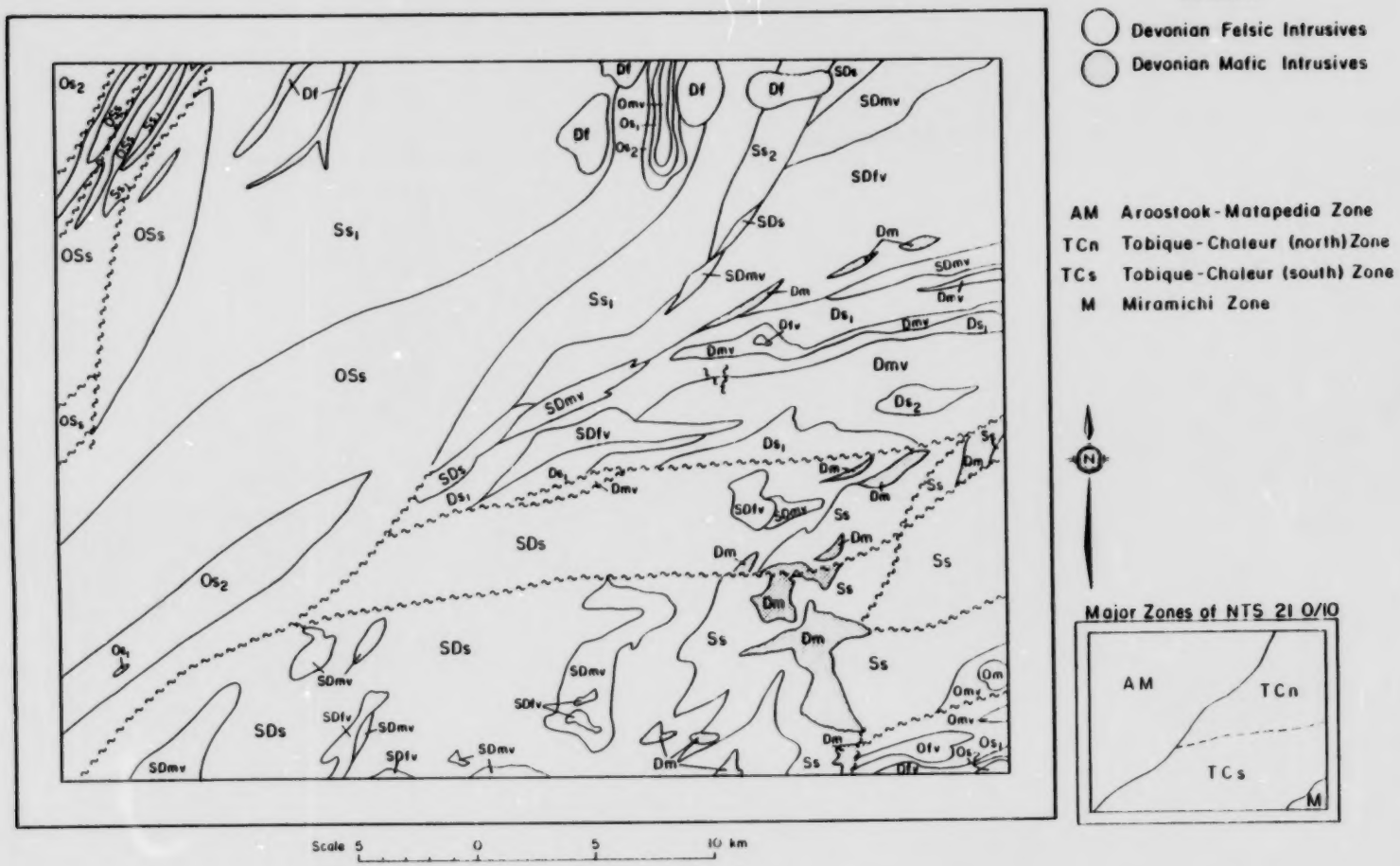

FIGURE 3. Geology of Upsalquitch Forks map area (NTS 21 O/10).

LEGEND

DEVONIAN

Df	Felsic to intermediate intrusions
Dm	Mafic to intermediate intrusions
Dmv	Porphyritic and amygdaloidal basalts, locally pillowed; mafic tuffs
Dfv	Felsic pyroclastic rocks
Ds2	Green-grey conglomerate, arkosic sandstone, and grey siltstone
Ds1	Green and grey, micaceous, slightly calcareous slate and sandstone; minor basaltic and rhyolitic flows and silty fossiliferous limestone.

SILURO-DEVONIAN

SDmv	Mafic lavas, agglomerates, and tuffs
SDfv	Felsic lavas and pyroclastics
SDs	Grey, green, and red siltstone, and micaceous sandstone; minor fossiliferous limestone and crinoidal sandstone; locally volcanic rocks and conglomerate

SILURIAN

Ss2	Grey fossiliferous and silty limestone, green sandy limestone; minor maroon shale, grey calcareous shale
Ss1	Grey calcareous siltstone and sandstone with minor fossiliferous limestone
Ss	Undivided Silurian sedimentary rocks

UPPER ORDOVICIAN TO LOWER SILURIAN

OSs	Dark grey to blue, thinly bedded, fine-grained limestone with interbedded calcareous slate

ORDOVICIAN

Os2	Dark grey, calcareous mudstone (locally fossiliferous) with interbedded medium-grained sandstone and limestone
Os1	Dark grey slate (locally graptolitic), red slate, green and black chert
Om	Metagabbro and metadiabase
Omv	Mafic metavolcanic rocks
Ofv	Felsic metavolcanic rocks

silicification and brecciation have yielded up to 5200 ppb Au and 921 ppm Ag. The fracture zones may be associated with a major felsic intrusion at depth, because there is a large gravity anomaly in this area.

2. Intrusion-hosted systems are common in Silurian to Lower Devonian sedimentary rocks of the southern part of the Tobique-Chaleur Zone (TCs), (Figure 3). Three types are present as follows:

a. Auriferous mafic intrusions and associated breccias - The mineralization is associated with intense silicification and carbonatization manifested by abundant quartz-siderite veining. Diamond drilling has indicated alteration zone thickness in excess of 200 m. Assay values from these zones are as high as 15 000 ppb Au.

b. Auriferous intermediate to felsic intrusions - Altered feldspar porphyry and minor quartz-feldspar porphyry exhibit the same alteration as the mafic intrusions, but they are much less widespread. Gold values recorded thus far are in the 200-1000 ppb range. Relatively large felsic intrusions are common in the northern part of the area in the Aroostook-Matapedia (AM) Zone (Figure 3). Grab samples indicate that some of these are geochemically anomalous in gold (10-40 ppb), but no spatial association is apparent between till-geochemical anomalies and these intrusions.

c. Polymetallic auriferous quartz-calcite veins in mafic intrusions - The only known occurrence of this type in the area is associated with an altered diorite that lies near the eastern edge of the Aroostook-Matapedia zone. The veins carry up to 10 350 ppb Au and 350 ppm Ag.

3. Skarn-type systems are present in the northwestern part of the map area (Legacy or McKenzie Gulch deposit), and just north of the map boundary (Popelogan deposit; see Philpott, p. 19) where intrusions cut calcareous rocks of the Matapédia Group. The intrusions and their associated skarns have not been systematically tested for gold, but geochemically anomalous values have been obtained from grab samples.

PROJECT GOALS

Over the next few months the project will be concerned with:

1. Preparation of 1:10 000 scale maps, and a 1:50 000 scale map, for 21 O/10.

2. Examining results from geochemical assay and whole-rock analyses of samples taken during the 1988 season.

3. Petrographic study of whole-rock samples taken in 1988.

4. Preparation of a computerized file of all geochemical assays for 21 O/10.

REFERENCE

BURTON, D.M., CREAMER, J., and MURPHY, B. 1987. In Twelfth Annual Review of Activities, Project Résumés, 1987. Edited by S.A. Abbott. New Brunswick Department of Natural Resources and Energy, Minerals and Energy Division. Information Circular 87-2, pp. 7-12.

PRECIOUS-METAL AND GEOLOGICAL INVESTIGATION OF THE CHARLO RIVER AREA, NEW BRUNSWICK

G.R. Philpott, MDA Project Geologist

The Charlo River area is located in northern New Brunswick approximately 35 km southwest of Dalhousie (Figure 4) mainly in the Tobique-Chaleur Zone (Davies 1979). A mapping and litho-geochemical sampling program (funded under the Canada-New Brunswick MDA) was conducted in the area to locate favourable alteration zones, test them for their gold potential and ascertain their geological setting.

Approximately 450 km^2, covering parts of map areas NTS 21 O/10, 21 O/15, and 21 O/16, were mapped at a scale of 1:10 000. Previous mapping in the area was done by Alcock (1935), Potter (1965), Greiner (1965; 1973a, b), Irrinki (1973a, b, c, d; 1974a, b), and Constable (1973a, b).

A total of 150 altered and/or mineralized samples have been analysed for the following elements: Au, Ag, Cu, Pb, Zn, As, Sb, Ba, W, Hg, Tl, Bi, F, Fe, Mo, Sn, and Se. The majority of these samples come from mineralized sedimentary and felsic intrusive rocks. Whole-rock and trace-element analyses have been performed on 28 samples in order to better understand the nature of the volcanic and intrusive rock types.

STRATIFIED ROCKS

The study area contains four groups of rocks: Balmoral Group (name to be formalized in a future publication), Matapédia Group, Chaleurs Group, and Dalhousie Group.

The Balmoral Group consists of two formations. The Goulette Brook Formation (Unit Omv, Figure 5) is made up of an upper mafic lapilli tuff member and a lower ultramafic hyaloclastite member. It is conformably overlain by the Popelogan Formation (Unit Os), composed of black graptolitic slate and chert. Graptolites recovered from the slate by L.R. Fyffe and identified by John Riva of Laval University give a Late Ordovician (Caradocian) age for the top of the Balmoral Group.

Trace-element geochemistry shows that the upper lapilli tuff is andesitic in composition (Figure 6), whereas the lower hyaloclastite is basaltic. The high MgO, Cr, and Ni values (15%, 2000 ppm, and 600 ppm respectively) indicate that the lower hyaloclastite unit is a picritic basalt.

The Matapédia Group (Unit OSs, Figure 5) is Ordovician to Early Silurian in age and disconformably overlies the Goulette Brook Formation. In the study area, the basal part of the

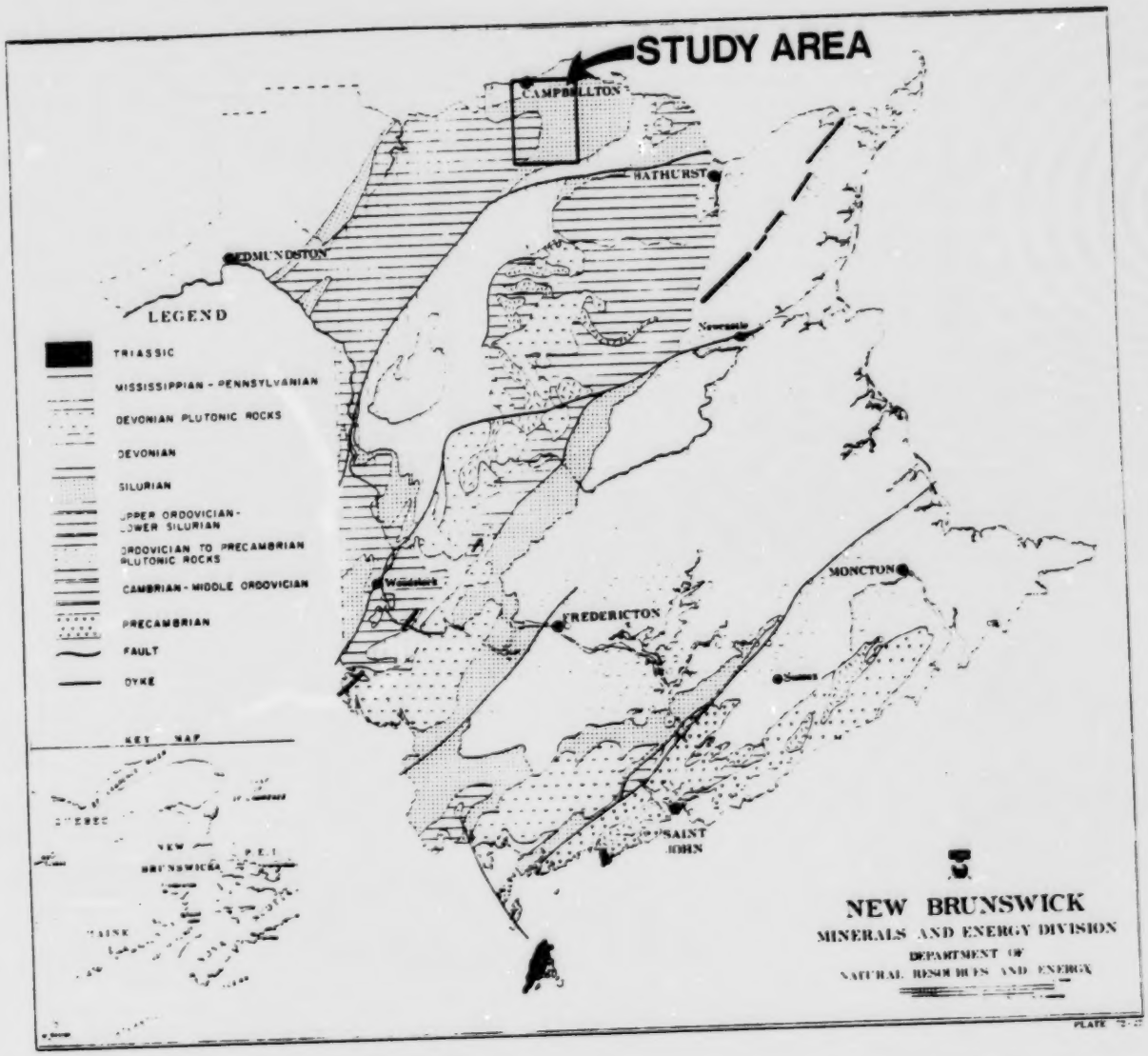

FIGURE 4. Geological map of New Brunswick showing location of study area.

Matapédia Group consists of calcareous shale and grit (3 to 10 m thick, similar to the Grog Brook Group of St. Peter (1978). The grit contains clasts of the underlying cherts of Unit Os, indicating an erosional contact between the Matapédia Group and the Goulette Brook Formation. The Matapédia Group, which mainly consists of thin-bedded limestone with very thin shale interbeds ("ribbon-rock"), is considered to be a submarine slope deposit (Stringer and Pickerill 1980).

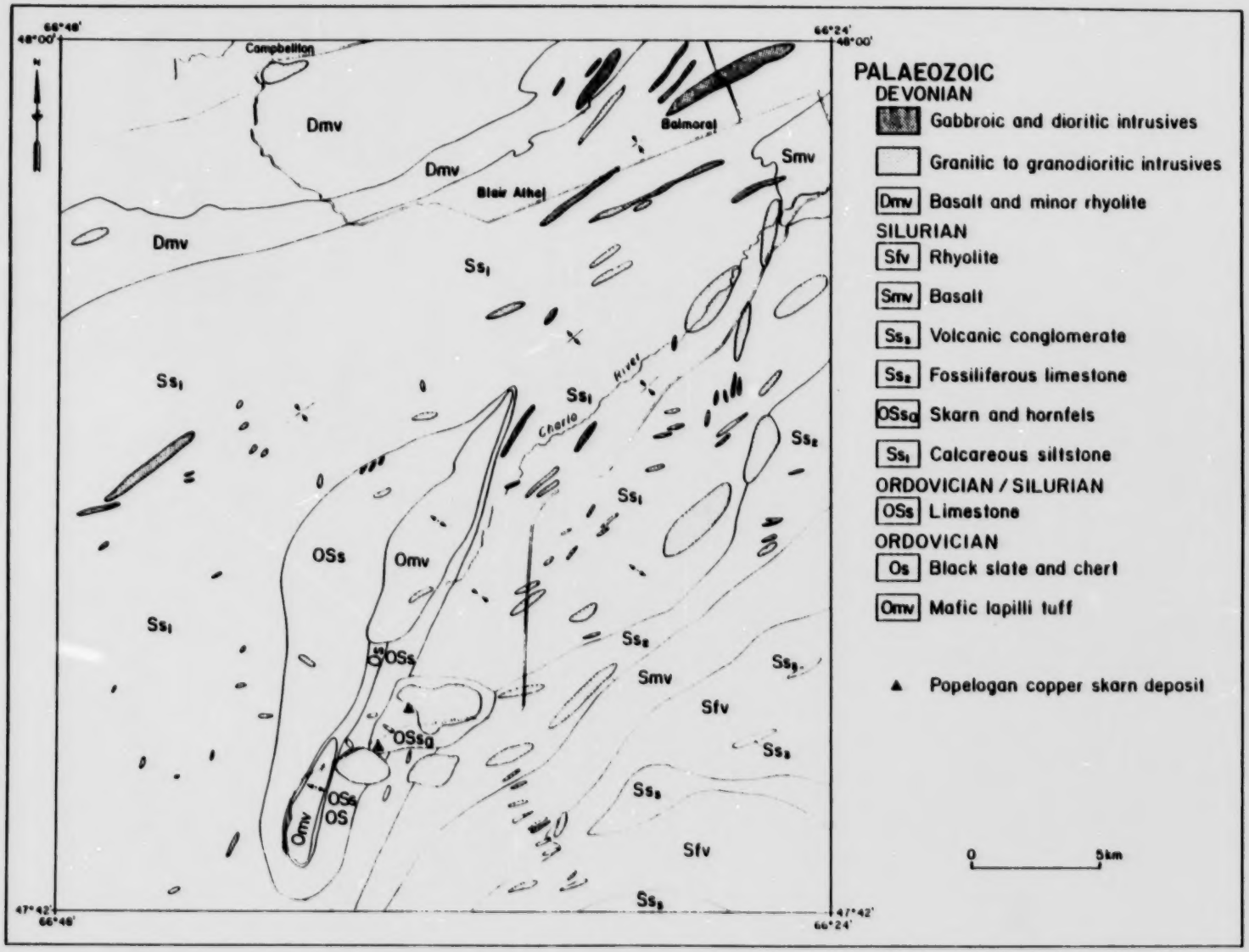

FIGURE 5. Geology of the Charlo River area.

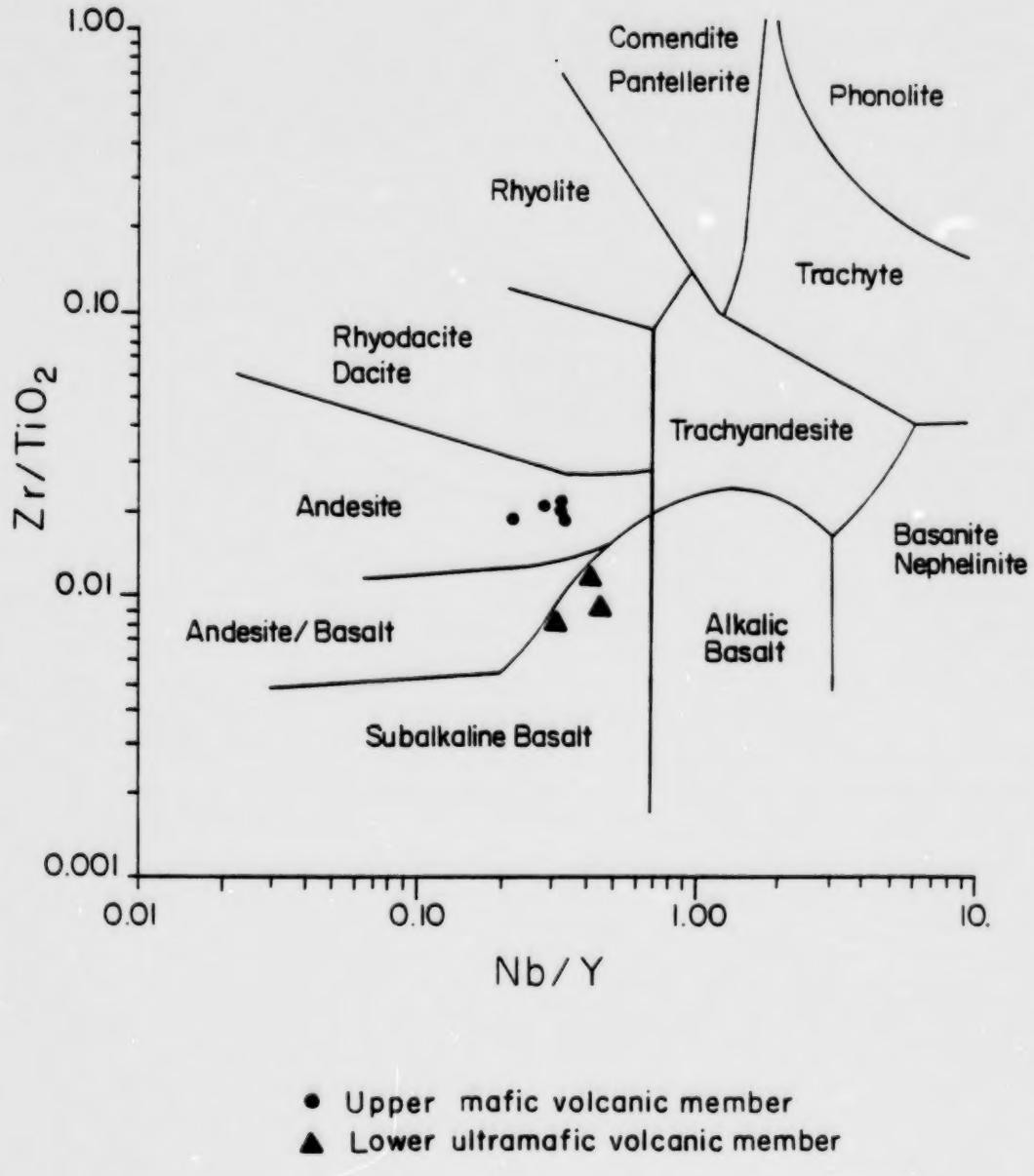

FIGURE 6. Zr/TiO_2 vs. Nb/Y discrimination diagram after Winchester and Floyd (1977).

The Silurian Chaleurs Group gradationally overlies the Matapédia Group. The basal part consists of shallowing-upward calcareous and noncalcareous siltstone of the Upsalquitch Formation (Unit Ssl, Figure 5) that is overlain by fossiliferous limestone of the La Vieille Formation (Unit Ss2, Figure 5). Mafic and felsic volcanic rocks of the Bryant Point and Benjamin formations, respectively, overlie the La Vieille Formation (Units Smv, Sfv, Figure 5).

INTRUSIVE ROCKS

Mafic and felsic intrusive rocks are abundant throughout the study area, mostly occurring as small dykes and sills that are too small to show on a large-scale map. The mafic intrusive rocks are greenish grey, fine- to medium-grained, feldspar-porphyritic gabbros and diorites. They are most abundant in the north around the villages of Blair Athol and Balmoral where individual dykes are up to 6 km in length and have a northeasterly trend. In part, the dykes are parallel to valleys that may outline northeast-trending faults.

Five textural-compositional varieties of felsic rocks are recognized and labelled A through E in Figures 7 and 8. They are as follows: Group A is a buff, nonporphyritic, microgranite that contains minor hornblende; Group B is pink to grey, porphyritic microgranite and/or feldspar porphyry with minor quartz-feldspar porphyry. Feldspar phenocrysts, mostly 1-3 mm in size, are set in a microcrystalline to cryptocrystalline groundmass; Group C comprises altered to unaltered microgranite. The altered microgranite is white in colour with dark grey pseudomorphs (3-5 mm) that are filled by quartz and white mica. The matrix is equigranular and composed of quartz and white mica. The unaltered microgranite is pink, and porphyritic with sparce phenocrysts of rounded quartz and plagioclase. The matrix contains feldspar, quartz, white mica after biotite and minor opaque minerals. Group D consists of pink to grey, medium-grained, equigranular hornblende granite to granodiorite; pink, biotite granite; and minor microgranite. The rocks contain plagioclase, quartz, chlorite, epidote, biotite, and white mica. The plagioclase is saussuritized and all the hornblende is replaced by chlorite. Muscovite is after biotite. Group E is grey, medium-grained, porphyritic granodiorite and granite. This group is the least altered. Plagioclase phenocrysts are only slightly saussuritized. The groundmass consists of orthoclase, quartz, biotite, chlorite, and epidote.

Even though many of the intrusive rocks are altered, a Hughes diagram (Figure 9) shows that the alkalies have not undergone major remobilization. Most samples plot within or close to the "igneous spectrum".

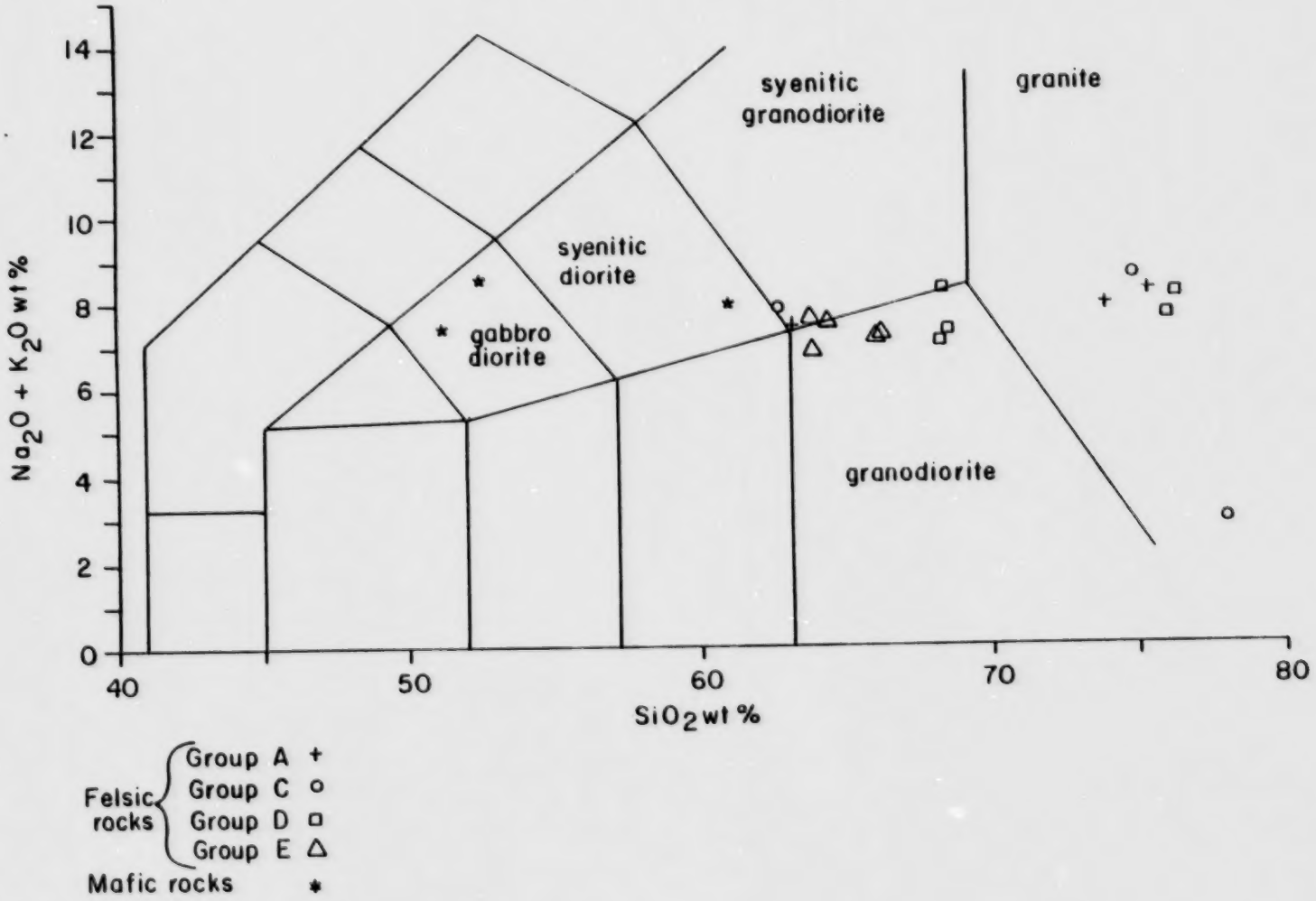

FIGURE 7. Total alkalies-silica discrimination diagram after Le Bas et al. 1986.

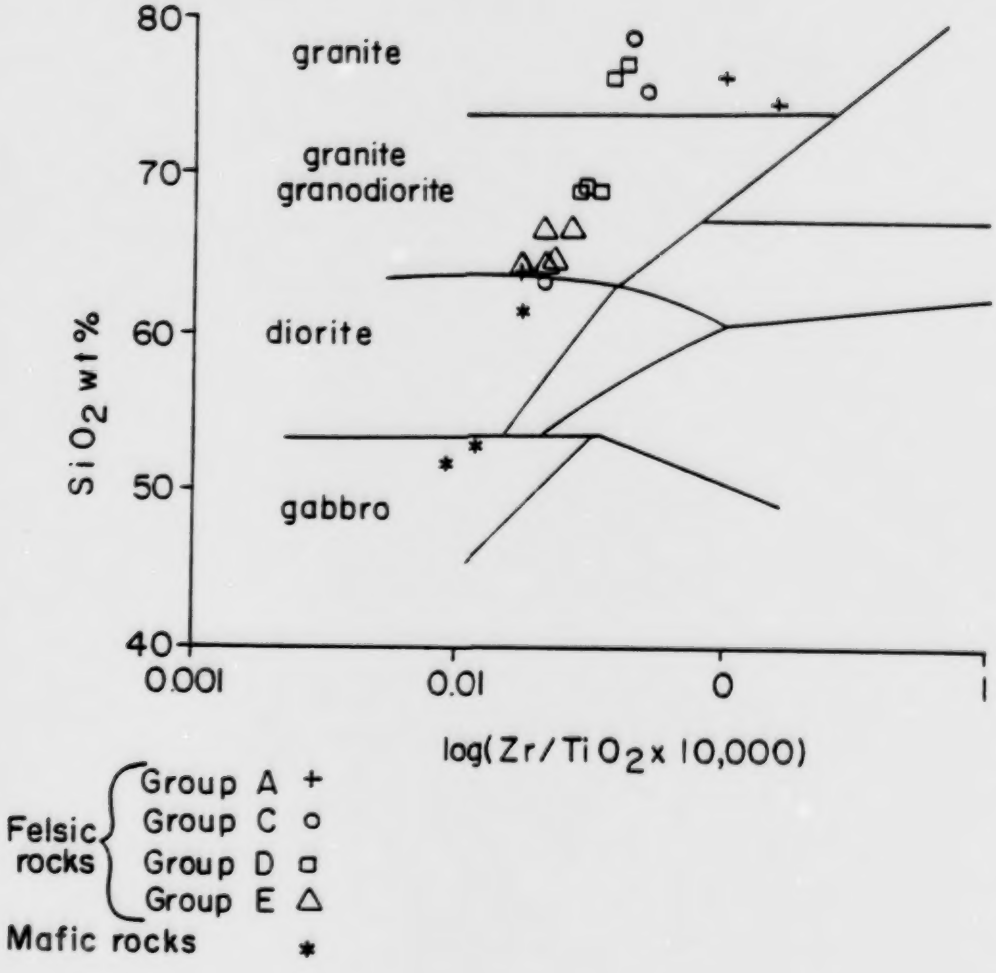

FIGURE 8. SiO_2 wt% vs. $\log(Zr/TiO_2 \times 10\,000)$ discrimination diagram after Winchester and Floyd 1977.

GOLD-BEARING ROCKS

It appears that the gold-bearing zones are related to intrusions and their surrounding host rocks. A generalized model is shown in Figure 10. Some mafic intrusions exhibit similar alteration and texture to gold-bearing mafic intrusions found in the Upsalquitch Forks area (Burton et al. 1987). Anomalous gold values ranging from 2 to 16 ppb have been obtained from grab samples. Background is less than 1 ppb. The highly siliceous altered to unaltered, microgranites of Groups A and C are auriferous. An unaltered microgranite, with no visible sulphide mineralization, yielded 14 ppb gold. These

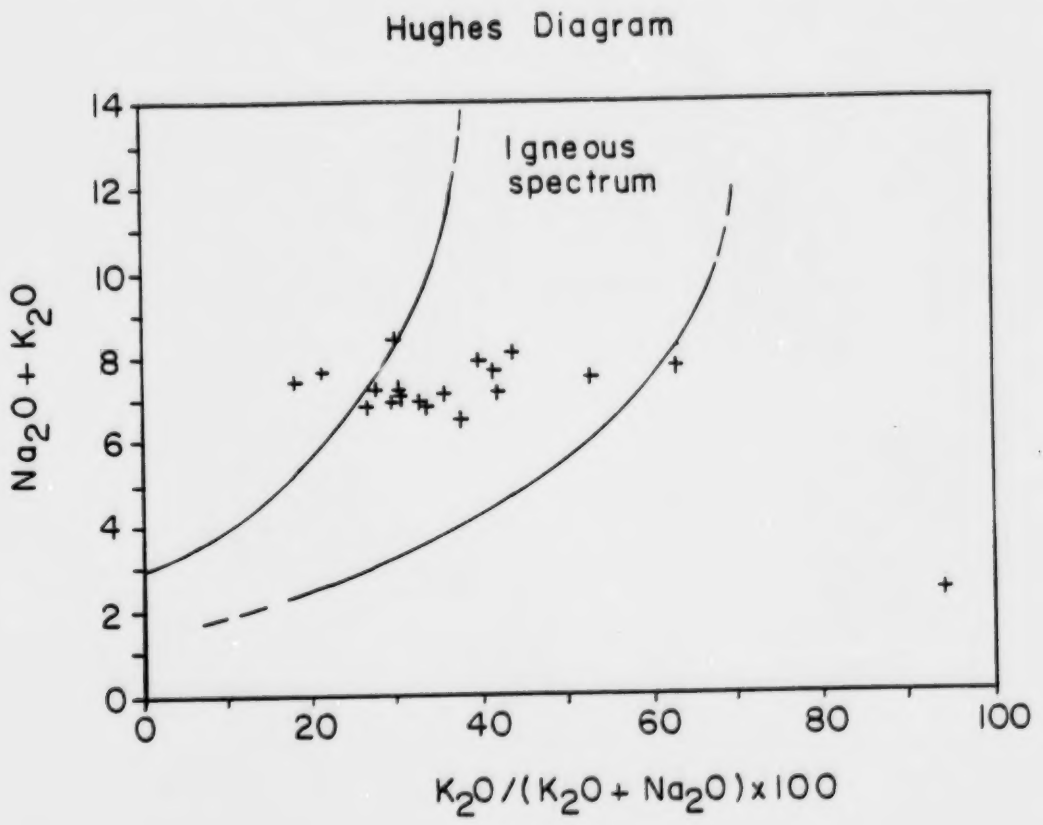

FIGURE 9. Na_2O+K_2O vs. $K_2O/(K_2O+Na_2O)$ x 100 discrimination diagram after Hughes 1972.

microgranites may represent a very high level siliceous cap that contained auriferous fluids. The porphyritic granodiorite of Group E is also auriferous; a grab sample yielded 14 ppb gold. Also Stratmat reported gold values in the 200-400 ppb range from their 1956 drilling program on the associated Popelogan copper-skarn deposit.

The Popelogan copper deposit was discovered in the mid-1950's after an aeromagnetometer survey outlined a magnetic high. The deposit contains 3.4 million tons of 0.3% copper. The main ore zone, described by Quartermain (1981) as a quartz-diopside skarn, does not outcrop at the surface. Gold associated with copper-skarn-porphyry systems has been well documented in recent years. Examples such as the Carr Fork Mine in the Bingham Mining District, Utah; Ok Tedi, Papua New Guinea; and Copper Canyon, Nevada all recover gold with their copper production (Beddoe-Stephens et al. 1987). The potential for gold mineralization in the Popelogan copper deposit will be tested by analysing the drill core.

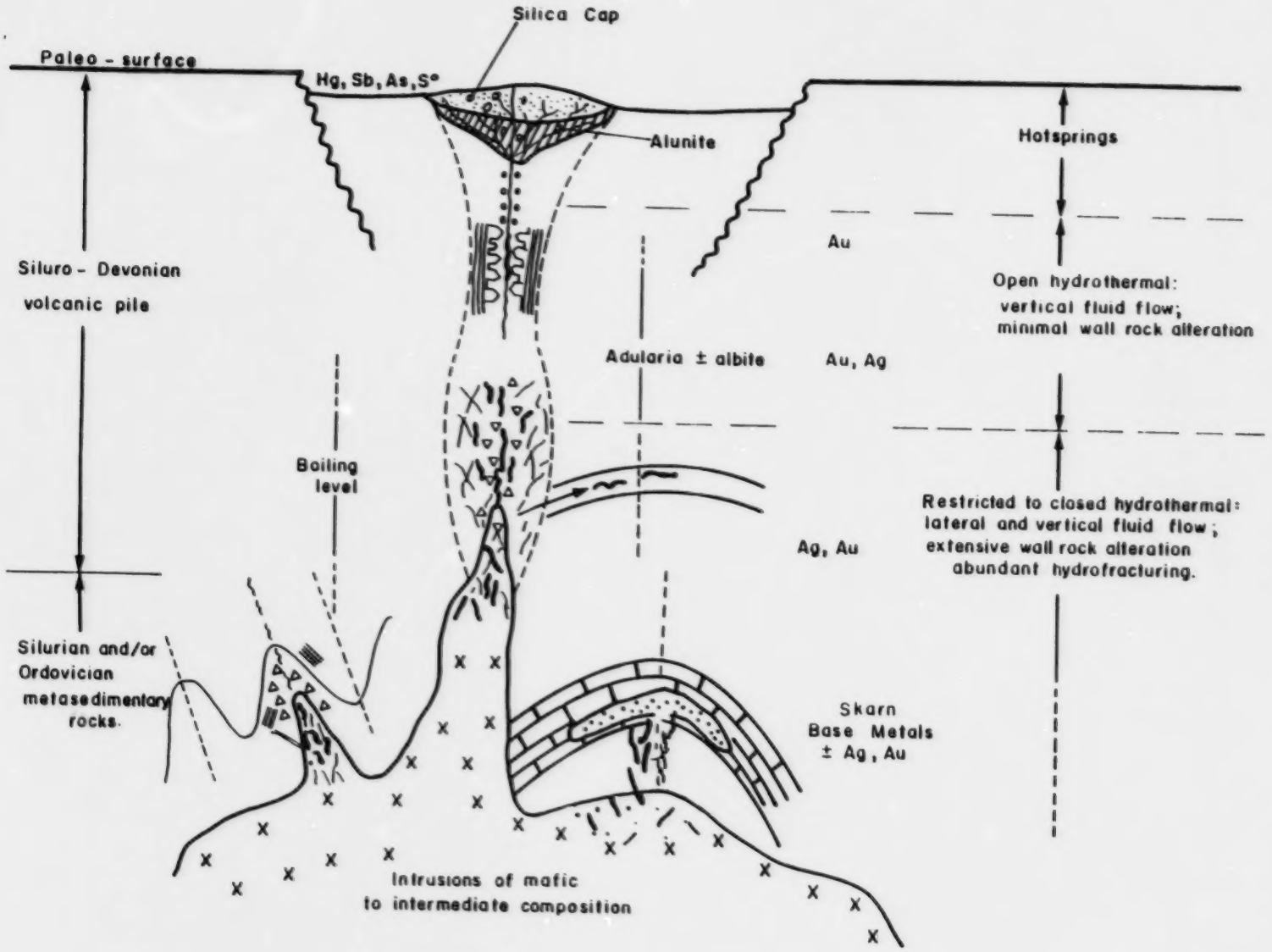

FIGURE 10. Idealized epithermal model from McCutcheon et al. 1988.

Known copper-gold skarn deposits such as the Carr Fork Mine in Utah (Cameron and Garmoe 1987) and the many disseminated gold deposits along the Carlin trend in Nevada all have associated plutonic rocks. The intrusions apparently drive the hydrothermal systems that deposit the gold.

CONCLUSION

The Charlo River area contains at least three favourable gold exploration environments: (1) gold associated with mafic intrusions, (2) gold associated with highly siliceous microgranites, (3) gold associated with porphyritic granodiorite and associated skarn.

Suggested exploration techniques include the use of gravity and gradiometer surveys to detect blind intrusive bodies, soil geochemical and lithogeochemical surveys, and detailed geological mapping.

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A DETAILED STRUCTURAL STUDY OF THE HEATH STEELE Zn - Pb - Cu - Ag DEPOSIT, NORTHUMBERLAND COUNTY, PROVINCE OF NEW BRUNSWICK: (MDA 1986-1989)

P.F. Williams & A.L. McAllister

GEOLOGY OF THE HEATH STEELE 'B', 'B-5', AND 'E' ZONES

C. Moreton

At least half a dozen polymetallic, base-metal massive sulphide deposits are exposed on the Heath Steele Mines property. Exploration for further reserves at the mine has been hampered by a lack of knowledge of the structural and stratigraphic relationships both between and within the individual deposits. It is the purpose of the present study to improve upon the understanding of these relationships so that future exploration targets can be better constrained. Three deposits have been studied by the author (known locally as the B, B5, and E zones) and the significant results of the analysis (to date) are given below.

Extensive trenching in the B and B5 areas has shown that the previous stratigraphic interpretations for the mine geology are incorrect (see McBride 1976, for example). On the east side of the B-pit, the felsic volcanic rocks of the B zone hanging wall clearly connect with at least one layer of McBride's (1976) 'footwall crystal tuffs'. This implies that all of the felsic volcanic rocks on the south side of the deposit are, in fact, the same age as the lithologically-similar rocks in the hanging wall. Their present location on the south side of the deposit merely reflects structural repetition by folding. Such an interpretation had been proposed earlier by the author, based on a detailed petrological analysis of thin sections of samples from all felsic volcanic layers in the study area. Further support for this reinterpretation of the mine geology has come from a geochemical analysis of the same felsic volcanic rock samples -- there is no significant trace-element geochemical variation between the samples suggesting derivation from the same source and probable deposition at the same time.

Thus, the mine geology is now simplified and the gross 'stratigraphic' relationships can be summarized as follows: the footwall to all of the deposits in the study area consists only of metasediments, while the hanging wall consists only of felsic metavolcanic rocks. Within the footwall unit, two subtypes are defined based on the presence or absence of pyrite. In the older "mine" terminology these two subtypes are known as the chlorite tuff and the acid tuff (pyritic). The pyritic variety often contains abundant sericite and is generally located closer to the favourable horizon. Overlying

the footwall metasediments are the polymetallic massive sulphides, and these in turn are overlain by the hanging wall felsic metavolcanic rocks. In the latter case, two lithotypes are defined, the quartz porphyry (adjacent to the favourable horizon) and the more abundant quartz-feldspar porphyry. All of the contacts between these three units, where observed, appear to be stratigraphic (although thrusted contacts cannot be ruled out). A fourth unit, known as the acid volcanics unit, is exposed on the south side of the study area. Its contact with the mine sequence is characterised by a well-foliated rock. Since this foliation is folded by F_2 folds, the contact must be D_1 in age. In the structural history proposed here, the contact would represent a D_1 ductile shear zone (see below).

Five fold generations have been documented at Heath Steele Mines. Tight to isoclinal F_1 fold closures are the dominant structures on the geological maps in the vicinity of the deposits. A three-dimensional diagram of the B zone deposit highlights a common characteristic of most of the deposits, namely the inclusion of macroscopic, hemi-ellipsoidal masses of country rock. These country rock lenses are geometrically consistent in that the eastern and western closures always appear to plunge toward the west. Since these structures are always overprinted by the S_2 foliation they must have formed during D_1. Their geometry is consistent with the interpretation that they represent F_1 sheath folds (or near sheath folds) which implies that D_1 was a relatively high strain event. A corollary of this statement is that the first tectonic event was probably characterized, in part, by thrusting. It is suggested that the foliated contact between the acid volcanics unit and the other units of the mine sequence represents a D_1 thrust zone.

In the B zone, F_2 folds overprint the D_1 sheath folds and generally have a more open style than the F_1 folds. Mesoscopic examples are not common even though the S_2 foliation is the strongest feature in most of the exposures. This foliation cannot be related to the F_1 sheath folds since the axial surface of the F_1 folds dips to the north, whereas the S_2 foliation dips to the south. It appears that the S_2 foliation is axial planar to an antiform that is larger than the scale of our mapping and since the foliation dips to the south, the F_2 fold must be overturned toward the north. In a few exposures in the study area the main foliation is actually a crenulation cleavage of the S_1 foliation and consequently it is better to term it a composite foliation.

All of the post-D_2 structures are open and only locally reorient the strike of the beds. Therefore, in terms of the Heath Steele geology and the localization of the mineralization, it is the F_1 (and possibly the F_2 folds) that are the most significant for exploration. Since the B zone is exposed on

the limb of a large F_2 antiform, those areas to the north and south of the B zone would be underlain by corresponding synformal structures. This is significant since the Brunswick #6 and #12 deposits are located in basins created by the intersection of F_1 and F_2 folds).

APPLICATION OF REMOTE SENSING IN THE SEARCH FOR MASSIVE SULPHIDES, HEATH STEELE MINES AREA, NEW BRUNSWICK

J.G. Torrance and M. Lodin

Owing to the paucity of rock exposure and the structural complexities in the Heath Steele Mines area of the Bathurst Mining Camp, geological interpretation of the region has been inhibited. It has been necessary to use very detailed geological mapping in order to understand the structure controlling the spatial distribution of sulphide deposits.

Multi-date LANDSAT MSS (Multi-spectral Scanner) and LANDSAT TM (Thematic Mapper) satellite digital imagery covering a 28 km by 20 km area (Figure 11) was acquired and analysed as part of this project. Detailed lineament extraction of the infrared spectral bands was performed using procedures described in the literature and algorithms designed by the authors. Multi-step directional filtering procedures, implemented on an ARIES II Digital Imaging System, were utilized in order to produce composite lineament maps. Fully annotated, continuous tone, MSS and TM base maps were plotted on paper using a Calcomp 5835 plotter. Binary colour image TM lineament plots were produced on acetate using the same hardware. Such maps contain combinations of selected lineament trends at a scale of 1:50 000. Various filter sizes, coefficients, and threshold limits were tested.

The results of the lineament extraction were digitally correlated with total field magnetic and vertical gradiometer data.

Computer search for multi-spectral characteristics (signatures) similar to those of known rock outcrops were conducted using discrete pixel and areal search parameters. An integrated approach combining both digital satellite imagery and interpolated airborne geophysical raster data was employed. Statistical analysis of each 1 km square grid unit (UTM map base) was completed. Results were used in the preparation of rock occurrence probability maps.

Spectral signature search for gossan/sulphide occurrences was conducted using the same technique. Several areally expansive targets, corresponding to potential gossan locations,

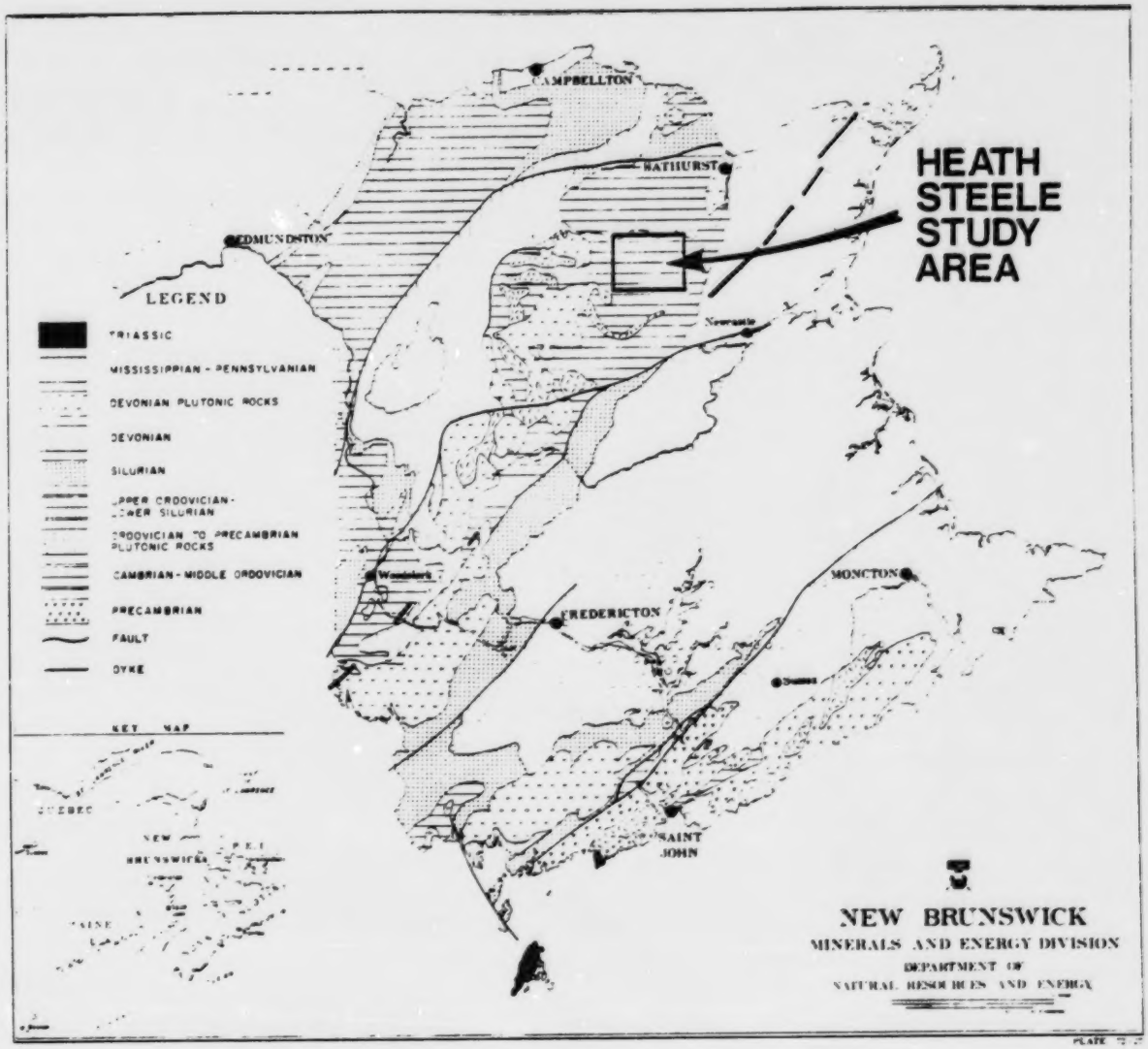

FIGURE 11. Location of Heath Steele study area.

were found to the north and east of the Heath Steele mine site. Alignment of many of these targets in an ENE-WSW direction corresponds to the general strike of the volcanic rock units in this region.

The processing of spatially registered digital image data from a variety of sources allows for rapid and varied integration of the available information. The integrated data base can be employed in the search for massive sulphide

deposits in the volcanic terrain of the Bathurst camp by enabling the resolution of possible gossan occurrences, gross stratigraphic distributions, and geological structure (faulting) in areas of little or no exposure. Ease of correlation with geophysical data affords a here-to-fore unavailable tool for the exploration geologist.

GEOSCIENTIFIC COMPILATION PROJECT (MDA)

J.L. Davies, Director of Geological Surveys Branch

The geoscientific compilation project was initiated in the fall of 1986 after a survey of various geocompilation projects across Canada. NTS sheet 21 O/8 was selected for the initial contract. This sheet was divided into 25 - 1:10 000 scale subsheets according to a convention established after discussions within the Department of Natural Resources and Energy. Subcontractors for the initial geoscientific compilation sheet were Three-D Geoconsultants Ltd. and K.D.A. Whaley, both of Fredericton. LRIS (formerly MRMS) of Amherst prepared the topographic-cultural base maps. Project manager was Northeast Exploration Services of Bathurst, N.B.

Data are recorded on five layers or overlays, several of which are exhibited here today. They are:

1. topographic-cultural base map.
2. geological-diamond drilling layer.
3. geophysical layer.
4. geochemical layer.
5. Annotations layer.

Because of the abundance of data, it was at times necessary to use more than one sheet for data plotting of each layer.

A standardized legend and series of Assessment Data Recording Sheets were also prepared in conjunction with the geocompilation in order to assist the end user in interpreting and analysing the data. Reliable assessment data are plotted on the map sheet and entered on the appropriate data sheets. Geological interpretation and synthesis presently underway are the responsibility of the Department of Natural Resources and Energy.

Preliminary examination of the data suggests that the compiled maps will be beneficial in:

1. locating areas where additional exploration is warranted because of coincident anomalies.
2. indicating areas in the vicinity of known deposits where only limited exploration has been completed.
3. providing a database indicating existing work to which additional recorded assessment work can be inputted.
4. indicating the surplus or paucity of specific recorded assessment data in New Brunswick (e.g., Au analytical data).

The delay in the project has stemmed from the lack of 1:10 000 scale geological maps, and the uncertainty regarding the adoption of a government geographic information system (GIS). The old 1 inch equals 1/4 mile map series has been replaced by a 1:10 000 scale map series, and it is hoped that all data can be released soon.

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GEOLOGICAL SURVEYS BRANCH

SUSSEX REGIONAL OFFICE

ACTIVITIES OF THE SUSSEX REGIONAL OFFICE

A.A. Ruitenberg, Regional Geologist

The Sussex Regional Office is staffed by A.A. Ruitenberg (Regional Geologist), M.J. McLeod (Asst.Regional Geologist), J.M. Mazerolle (Engineering Technician and Claims Inspector), and F.H. Kelly (Administrative Services Officer). S.E. Watters, D.G. Rose, and S.C. Johnson are employed under the Canada-New Brunswick MDA. P.G. Chiswell, D. Hanley, S. McDonald, A.D. Roy, and J. Todd were hired as field staff for the summer and fall field seasons.

PROGRAMS AND PROJECTS

M.J. McLeod completed field checking and finalized 1:20 000 geological maps of the Saint George Batholith. Work on the final report has started and will include a description of the various phases of the batholith, and a compilation and interpretation of all petrochemical data and petrographic characteristics. The relationship between tin, tungsten, molybdenum, and gold occurrences and the evolution of the plutonic complex will be investigated.

S.E. Watters and A.D. Roy completed geological mapping and drill-core logging of the gold-bearing zones in the Cape Spencer-Black River area. A three-dimensional model of the ore zones was completed. Regional geological maps at a scale of 1:15 000 have been prepared and detailed maps and sections (scale 1:1500) of the ore zones are in progress. Extensive geochemical analyses were conducted in conjunction with petrographic examination to characterize the ore-forming processes. A sulphur-isotope study of pyrite from the ore zones will be used to interpret conditions of ore deposition.

D.G. Rose and S.C. Johnson completed the input of data into the computerized New Brunswick Mineral Occurrence File. Thorough editing and revision of the file are in progress, along with some field checks. Summaries of occurrence data were prepared for inclusion in reports of the Heath Steele, Burnthill, and Charlo areas.

P.G. Chiswell mapped and supervised the geochemical sampling of the tills overlying the gold-bearing Ordovician and Silurian rocks in the western part of the Rollingdam map area (21 G/6W). This area is part of the Honeydale thrust-fault zone that extends to the southwest into the State of Maine.

A.A. Ruitenberg and M.J. McLeod remapped some of the gold-bearing structures in the Dipper Harbour, Little Dipper Harbour, and Musquash Harbour areas, southwest of Saint John. The main gold-bearing veins and stockworks in this area are associated with thrust-fault zones similar to the Cape Spencer-Black River area northeast of Saint John. Revised structural interpretations are presented in the N.B. Gold Symposium field guide to gold deposits of the Bay of Fundy coastal zone and Saint George Batholith area (Ruitenberg *et al*. 1988).

The entire staff of the Sussex Regional Office was involved in the organization of the gold symposium, which was attended by about 100 geologists and prospectors from across Canada and the United States. S.E. Watters and A.A. Ruitenberg prepared papers for the symposium.

A paper on gold deposition related to crustal thickening along major tectonic boundaries in New Brunswick was presented at the 1988 Annual Meeting of the Prospectors and Developers Association in Toronto (Ruitenberg and Fyffe 1988). Ruitenberg presented a paper on deformation in Quaternary deposits of southwestern New Brunswick at the Annual Meeting of the Geological Association of Canada, in Saint John's, Newfoundland (Ruitenberg 1988a). He also prepared a paper on geological parameters in forest soil productivity for the Annual Meeting of the Northeastern Forest Soils Conference, in Fredericton (Ruitenberg 1988b).

The regional geologist participated in a committee charged with evaluating Mineral Exploration Stimulation Program (MESP) proposals. In total, thirty-one grants were approved for prospectors and small exploration companies.

M.J. Mazerolle drafted the final maps for the Mount Pleasant Caldera project, the surficial geology and geochemistry maps of the Eastern Rollingdam area (21 G/6E), figures for the Bay of Fundy coastal zone gold deposits field guide and started work on 1:20 000 geological maps of the Saint George Batholith and the Cape Spencer-Black River area. Assessment report summaries were computerized, including important mineralized drill-core intersections. Mr. Mazerolle also carried out several claim inspections in the field.

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SAINT GEORGE BATHOLITH PROJECT

M.J. McLeod, Assistant Regional Geologist

Detailed investigation of the geology of the Saint George Batholith and its economic potential is continuing; a comprehensive report will be finalized by March 1989. Mapping and geochemical sampling have been completed and 1:20 000 maps have been prepared. The results are summarized on Figure 12. In conjunction with the mapping and sampling program, detailed petrographic, geochemical, and chronological studies have been undertaken. All available geochemical and assay data have been compiled and will be included in the final report.

The Saint George Batholith is composed of several, mainly granitic, intrusions that range in age from early to late Devonian. Descriptions of the various intrusions are given by McLeod et al. (in press), McLeod (1987), Gardiner (1987), Thomas et al. (1983), and Cherry (1976) and will not be reiterated here. The batholith is essentially divisible into eastern and western parts.

The Mount Douglas granite (Unit Dmd), which constitutes the eastern part, was emplaced circa 367 Ma (McLeod et al., in press) and contains significant endogranitic Sn-W-bearing sheeted vein occurrences. These occurrences are related to the youngest, most highly differentiated phases of this pluton (Unit Dmd3).

The western part is composed of several intrusions including the Bocabec Complex (Unit Dbc), the Utopia granite (Unit Du), the Magaguadavic granite (Units Dm1 and Dm2), and the John Lee Brook granite (Unit Djl). The Utopia, Magaguadavic, and John Lee Brook granites yield $^{40}Ar/^{39}Ar$ total gas ages of 418 Ma, 400 Ma, and 371 Ma respectively (unpublished data). These granites, particularly near their contacts, are host to numerous vein and fracture-fill-type Mo and Cu mineral occurrences. The equigranular phase of the Magaguadavic granite (Unit Dm2) is locally greisenized and contains disseminated W and Sn with associated Pb and Cu.

Gold showings are known in the contact aureole of the batholith but have not yet been found within it. Extensive descriptions of some of these occurrences are presented by Ruitenberg et al. (1988). Auriferous occurrences are found either in silicified shear and quartz-veined, dilatent zones adjacent to the Mount Douglas granite (Unit Dmd) or in quartz +/- carbonate veins and silicified zones in the vicinity of the Magaguadavic granite (Unit Dm). These are hosted primarily in Silurian sedimentary rocks along the northwest margins of the batholith, but also occur in late Proterozoic rocks to the east. Arsenopyrite, pyrite, and low but anomalous values of Bi and Sb normally characterize the auriferous zones. Base metals

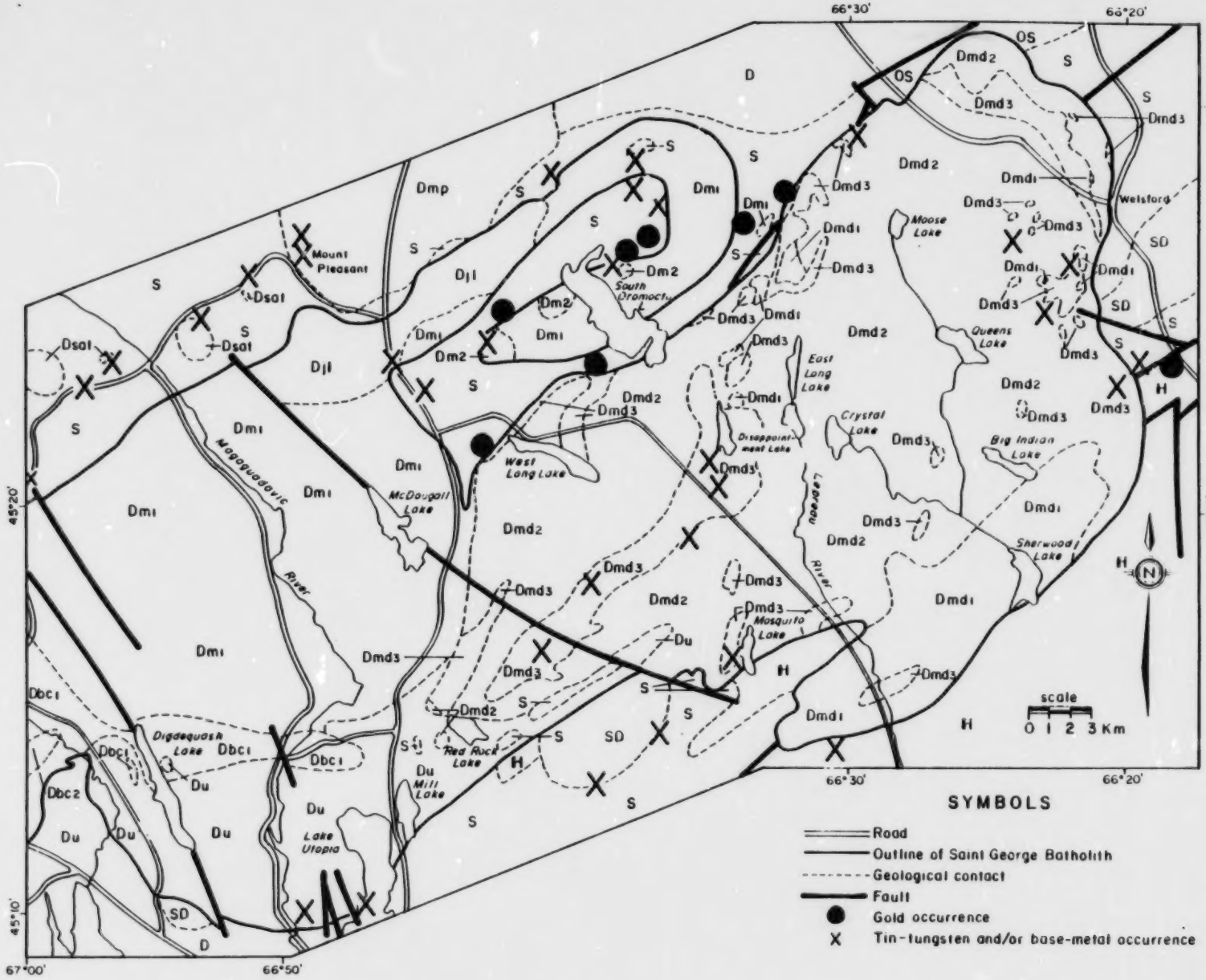

FIGURE 12. Geology of the Saint George Batholith.

LEGEND

LATE DEVONIAN

MOUNT PLEASANT CALDERA COMPLEX

Dmp — Felsic and mafic volcanic rocks; sedimentary rocks and fine-grained biotite granite

TRUE HILL, BEECH HILL, BONNY RIVER, AND PLEASANT RIDGE STOCKS

Dsat — Satellite stocks; mainly pink, fine- to medium-grained, equigranular and porphyritic biotite granite

MOUNT DOUGLAS GRANITE

Dmd — Dmd3. Red, medium-grained, equigranular, biotite granite, pink to grey, porphyritic, biotite microgranite and aplite, and grey, equigranular, biotite microgranite

Dmd2. Pink and buff, medium- to fine-grained, seriate, biotite granite; minor microgranite and granophyre with abundant miarolitic cavities and medium- to coarse-grained, seriate, biotite granite with abundant coarser crystals of quartz and rapakivi feldspar.

Dmd1. Coarse-grained to very coarse grained, seriate, biotite + hornblende granite with well-developed, rapakivi textures; minor porphyritic microgranite locally with a cryptocrystalline matrix.

EARLY TO MIDDLE DEVONIAN

JOHN LEE BROOK GRANITE

Djl — Grey, medium-grained, equigranular biotite + muscovite +/- garnet granite.

NAGAGUADAVIC GRANITE

Dm — Dm1. Pink to grey, coarse-grained, porphyritic, biotite and hornblende granite with minor quartz monzonite and granodiorite; locally medium grained and seriate.

Dm2. Pink, fine- to medium-grained, equigranular and slightly porphyritic, biotite granite; locally contains abundant miarolitic cavities and disseminated pyrite +/- chalcopyrite.

UTOPIA GRANITE

Du — Pink to red, medium-grained, equigranular, biotite granite

BOCABEC COMPLEX

Dbc — Dbc2. Pink, medium-grained, equigranular, biotite granite

Dbc1. Green, medium- to coarse-grained gabbro and diorite

DEVONIAN

D — Sedimentary rocks, felsic and mafic volcanic rocks

SILURIAN OR DEVONIAN

WELSFORD COMPLEX, JAKE LEE MOUNTAIN COMPLEX, AND PARKS BROOK GRANITE

SD — Mainly alkaline granitic rocks

SILURIAN

S — Sedimentary rocks, minor felsic and mafic volcanic rocks; minor mafic intrusions

ORDOVICIAN OR SILURIAN

OS — Sedimentary rocks

LATE PROTEROZOIC

H — Granitoid rocks, felsic volcanic and sedimentary rocks

and less commonly Sn- and W- bearing minerals may be present. Most occurrences appear to be related to the major northeast-trending and minor north- to northwest-trending faults that typify the tectonics of the Acadian Orogen prior to pluton emplacement.

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GOLD-BEARING ROCKS - BAY OF FUNDY COASTAL ZONE

S.E. Watters, MDA Project Geologist

Field work during 1988 on gold-bearing rocks along the Fundy Coastal Zone involved logging of recently drilled cores at Cape Spencer and completion of geological mapping in the Cape Spencer to Black River area. The geological relationships interpreted in the vicinity of the gold deposits are shown in Figures 13 and 14. The area in Figure 13 is part of a Hercynian fold and thrust belt exposed along the Fundy Coastal Zone of southern New Brunswick. This part of the belt is dominated by northwest- and southeast-directed conjugate thrusts and associated folds involving Precambrian volcanic and granitoid rocks as well as Carboniferous sedimentary rocks. Gold deposits at Cape Spencer are controlled by these structures (Ruitenberg 1984; Watters 1985, 1986, 1987, 1988).

Relogging of this core indicates that the Precambrian Millican Lake granitoid rocks are thrust over arkosic sedimentary rocks of the Cape Spencer Formation (informal name). Locally, the unconformity between Cape Spencer Formation basal conglomerate and the Millican Lake granitoid rocks is preserved. The Mispec Resources "Road Zone" deposit, which is exposed on surface in the Cape Spencer Formation, is concealed along strike to the southwest beneath this granitoid thrust sheet (Figures 13 and 14). These structural relationships indicate the potential for hidden orebodies.

Geochemical analyses of unaltered rocks and their altered equivalents are presently being examined. The gold ores occur in argillic alteration zones characterized by illite and/or sericite. Uncorrected values for potassium are strongly elevated in the argillic altered equivalents of all the igneous and sedimentary lithologies analysed. This suggests the possibility of radiometric detection of the ore-related alteration. Other elements, showing less consistent variation, are presently being evaluated in conjunction with petrographic studies of argillic, chloritic, siliceous, and carbonaceous alteration types. Argillic alteration zones cutting across hematite-rich sedimentary and igneous rocks are generally richer in pyrite than those that cut rocks relatively low in iron.

In addition to alteration studies, petrographic work has focused on microstructural interpretation. Preliminary conclusions are: 1. Low-grade Hercynian metamorphism appears to coincide with and/or postdate a penetrative S_1 cleavage in the Carboniferous Lancaster Formation and older rocks; 2. The relationships between carbonate porphyroblasts and the S_1 and S_2 cleavages in the Cape Spencer and Lancaster formations are

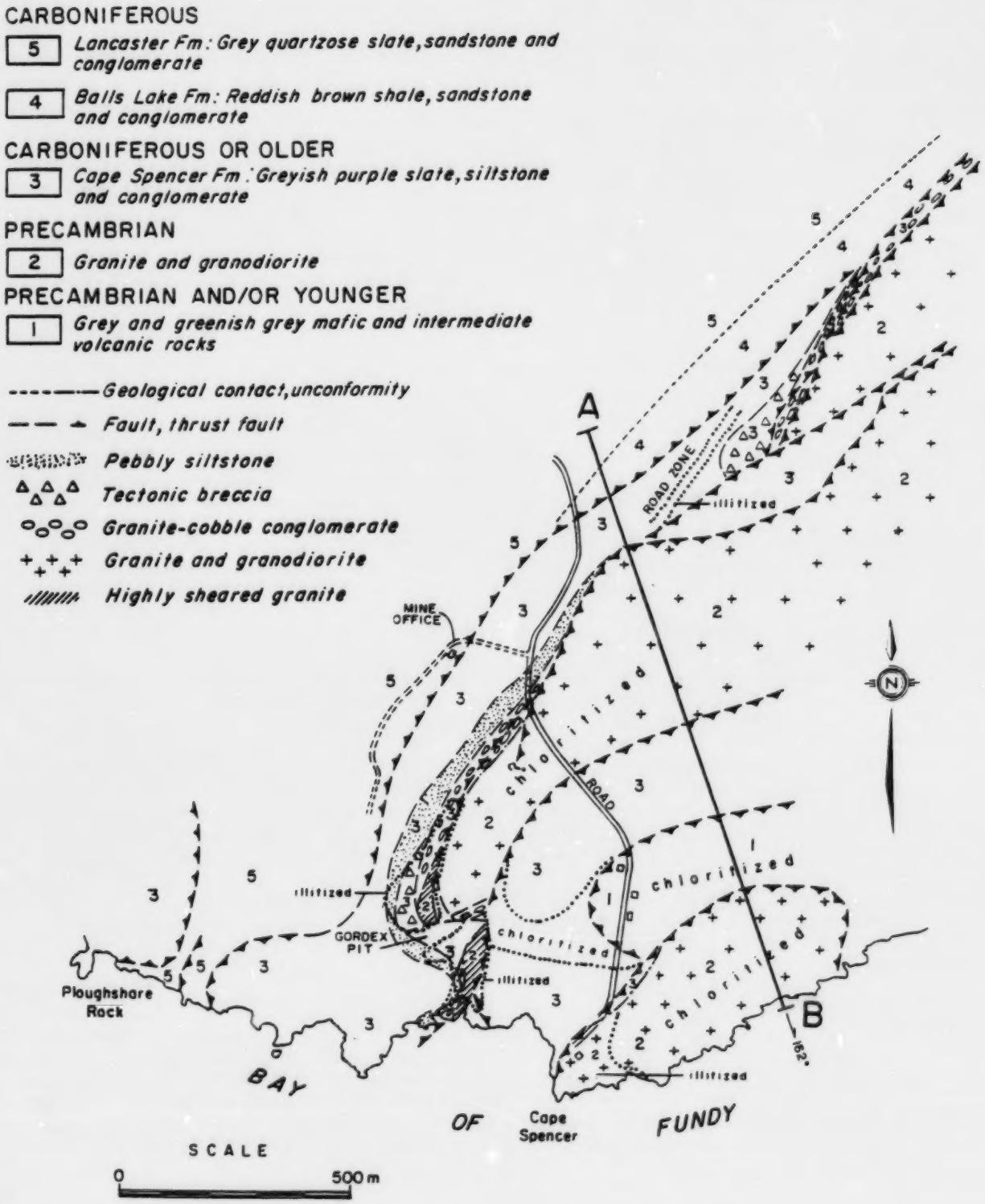

FIGURE 13. Geology in vicinity of gold deposits, Cape Spencer.

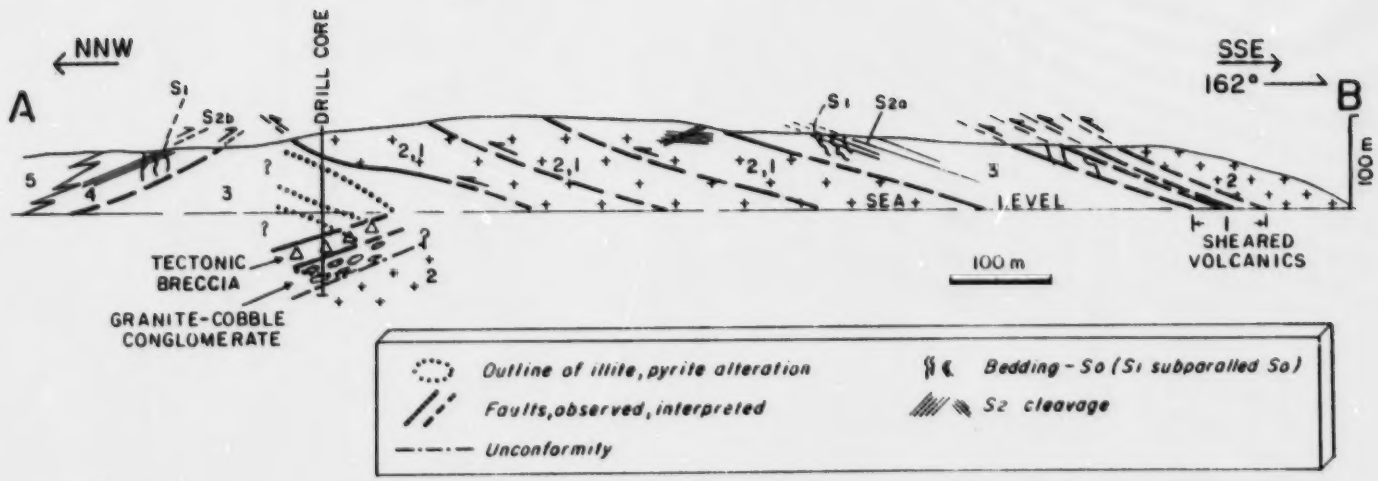

FIGURE 14. Cross-section A-B from Millican Brook to Bay of Fundy near Mispec Resources - Gordex property boundary (location and legend on Figure 13).

similar, which permits correlation of microstructures between these rock units; and 3. Petrographic observations are consistent with the previously reported syn-S_2 gold mineralizing event. Pyrite grains host much of the gold at Cape Spencer and some gold is enclosed completely within the grains. Some of the pyrite grains contain host-rock inclusions exhibiting a cleavage, therefore, they postdate the S_1 cleavage. Evidence from pressure shadows on pyrite grains from ore zones shows rotation of fully developed pyrite grains along the S_2 cleavage. This indicates that some pyrite had formed prior to final movement on S_2 cleavage. Widespread occurrence of pressure shadows adjacent to pyrite grains and parallel to the S_2 cleavage substantiates this conclusion.

A variety of pyrite samples were sent for sulphur isotope analysis for the purpose of interpreting ore-fluid sources. Pyrites from ore zones and from a variety of illite-altered and unaltered rock types were selected.

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NEW BRUNSWICK MINERAL OCCURRENCE FILE

D.G. Rose and S.C. Johnson, MDA Project Geologists

Input of data, begun in 1986, has been completed and accounts for all occurrences documented in the files of the Geological Surveys Branch. D. Hattie and A.A. Ruitenberg began to compile mineral occurrence and metallogenic map data in 1984 (Gouthro 1986). There are 791 occurrences in the computerized file to date.

A thorough review and edit of all data in the file is under way and will be completed in late autumn, 1988. Following the review, a description of the file and a user guide will be written for public release. To facilitate access to the data by non-specialists, a system has been developed which will simplify extraction of information from the data base and allow presentation of the data in a report format.

During the summer of 1988, in an attempt to obtain accurate location measurements, a portable Loran C navigation instrument was tested. It was hoped that the Loran C system, which works well on boats and aircraft, would provide a means of measuring mineral occurrence locations very precisely. Unfortunately, the instrument's accuracy was not sufficient for this application, probably because of errors introduced when the radio waves pass through inhomogeneous media (land/water). A satellite-based navigation system is presently being considered and could be field-tested in 1989.

Following release of the mineral occurrence file for public use, the next phase of this project will be a systematic review of all assessment files on microfiche. The purpose is to identify and document any significant showings that are not in the Geological Surveys Branch mineral occurrence inventory, and to incorporate these data into the computer.

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SURFICIAL GEOLOGY AND GEOCHEMISTRY, ROLLINGDAM AREA

P.G. Chiswell, Project Geologist

Sampling of the western half of the Rollingdam map area (21 G/6W) was completed this year with the able assistance of D. Hanley and J. Todd. A total of 118 samples was collected from the B- and C-horizons in hand-dug pits. B-horizon samples will be analysed for gold. A- and B-horizons were measured and described to assist in forest-site classification.

Some minor modifications have been made to the previously mapped eastern half of the map area (Chiswell 1987). The drumlinized area in the south central portion of the map area has been re-interpreted as a normal basal till unit with minor drumlins or flutes as opposed to an area of extensive drumlinization. A northeast-southwest-trending area through the central portion of the map area has been delineated as an ice-disintegration zone consisting of ablation moraines and organic deposits (Figure 15).

The northwest corner of the map area has abundant drumlins and these decrease toward the southern margin of the map area. Within this drumlinized area are many remnant kettle holes that have subsequently been infilled by recent outwash and alluvial deposits.

Close inspection of the aerial photographs within this drumlinized terrain shows that an extensive drainage pattern formed between the drumlins. This drainage, along with damming caused by ice blocks, has generated extensive erosion of drumlins in some areas.

Initial pebble examination of samples taken from the lower and upper parts of the drumlins shows a wide variety of lithologies. The material in the drumlins appears to have been derived mostly from a Carboniferous polymictic conglomerate occurring in the northern part of the map area. Some well-rounded pebbles may have been derived from pre-glacial fluvial sediments. Further work is being done on the pebbles and matrix to establish the source of the till.

In the southeastern portion of the map area the basal till is more gently rolling, which is an expression of the bedrock surface in the area. The larger, more circular hills in the area have their ends fluted in the direction of ice movement.

The tills are generally of light to olive grey colour in the northern part of the area, grading down-ice to a dusky yellow-brown. The till is commonly greater than a metre thick, but along eskers and within drumlins may be 30 m thick. The ablation till ranges from a veneer in the northern portion of the map area to in excess of 10 m in the central portion. The ablation till is generally light olive brown in colour.

During the fall months, the till-lithology boundaries will be added to the map sheet as well as the till geochemical results. The resulting maps will be published as a composite of the 1987 and 1988 fieldwork.

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NOTE: See map on following page.

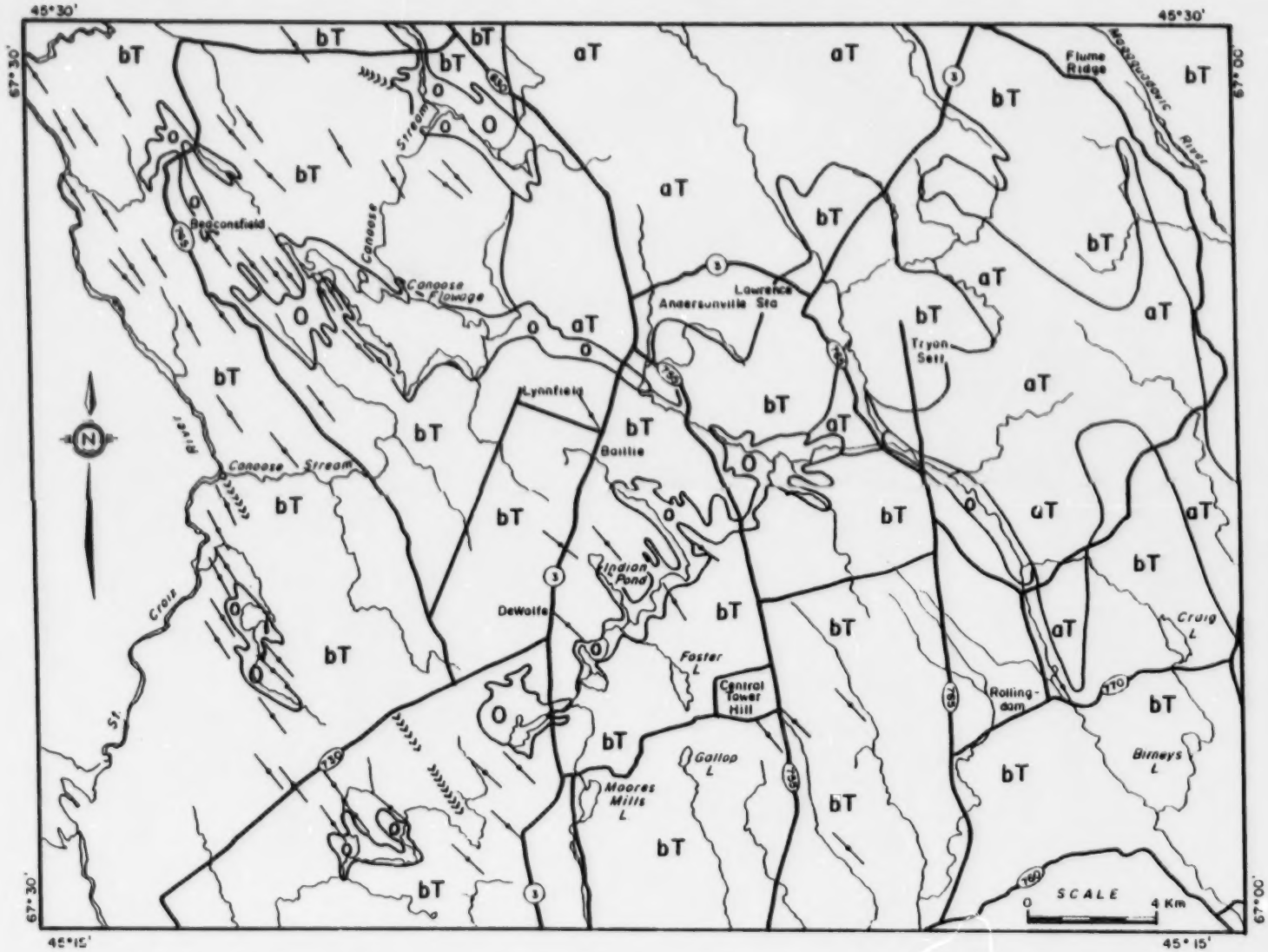

FIGURE 15. Surficial geology of the Rollingdam (21 G/6) map area.

LEGEND

O	Organic sediments	peat, muck, and silt; deposited in basins, kettle holes, and poorly drained areas; bogs and swamps, generally greater than 1 m thick
Gfo	Glaciofluvial outwash	sand and gravel; located along major drainage systems*
aT	Ablation till	boulders, gravel, sand, and clay, poorly compacted; includes some sand and gravel; found in hummocky and ribbed ablation moraines
bT	Basal till	moderate- to well-packed gravels with varying amounts of sand and clay; associated with moraines and drumlins

* Gfo unit is not shown on map due to the scale.

SYMBOLS

Drumlins

Eskers

Roads

Morphogenetic boundary

PUBLICATIONS 1988 - SUSSEX REGIONAL OFFICE

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GEOLOGICAL SURVEYS BRANCH

GEOSCIENTIFIC SERVICES SECTION

ACTIVITIES OF THE GEOSCIENTIFIC SERVICES SECTION

L.R. Fyffe, Senior Geologist

The Geoscientific Services staff, located at the Hugh John Flemming Centre in Fredericton, consists of L.R. Fyffe (Senior Geologist), R.R. Irrinki (Metallic Minerals Geologist), G.W. Crouse (Core Librarian), A.A. Seaman (Quaternary Geologist), V. Rinco (Geochemical Analyst), and B. Edney (Laboratory Assistant).

In addition to the regular staff activities, several projects were carried out by contract and summer personnel under the Canada-New Brunswick MDA. A.G. Pronk and M.A. Parkhill mapped the surficial geology, and R.A. Wilson and R.M. Sullivan mapped the bedrock geology of map area 21 O/3 (Riley Brook). H.E. MacLellan is compiling the field and lithogeochemical data on the tin-bearing granites of the Burnthill Brook area (21 J/10). L.R. Fyffe commenced mapping along the southwestern contact of the Pokiok Batholith (parts of 21 G/6 and 21 G/11). In addition, D. Kim is compiling a computerized geological bibliography of New Brunswick on dBase III+. There are approximately 2000 entries.

GEOLOGY AND LITHOGEOCHEMISTRY OF GRANITES IN THE BURNTHILL BROOK AREA - MDA

H.E. MacLellan and L.R. Fyffe

INTRODUCTION

Detailed geologic mapping of the tin-tungsten-bearing granites in the Burnthill Brook area (NTS 21 J/10 and part of 21 J/15) was completed in 1986. This mapping (NBDNRE Mineral Resources Division Plates; 86-241, 87-55, 87-57) has established that four rock units, based on differences in texture and mineralogy, are sufficient to characterize the main variations throughout the granite plutons. Argon-argon dating has confirmed field evidence indicating that these plutons were the latest in a series of intrusive events which began in the late Silurian (Taylor et al. 1987).

GEOLOGICAL SUMMARY

Epizonal, tin-tungsten-bearing granites of Middle Devonian age comprise the Burnthill, Dungarvon, Rocky Brook, Sisters Brook, and Trout Lake plutons in the central Miramichi Highlands (Figure 16). Four texturally and mineralogically distinct units are present in each pluton: Unit 1 is a medium-grained, melanocratic, biotite granite; Unit 2 is a coarse- to medium-grained, seriate, biotite granite; Unit 3 is a fine- to medium-grained, equigranular, biotite granite; and Unit 4 comprises dykes of aplite and porphyritic microgranite, and veins or pods of pegmatite and granophyric granite.

Average whole-rock chemical compositions of unaltered granitic phases show a trend consistent with fractional crystallization. All plutons contain geochemical signatures that are typically associated with anomalous concentrations of lithophile elements; average background tin values ranging from 10 to 35 ppm (compared to 3 ppm for average granite) reflect the specialized nature of these plutons.

Significant mineral occurrences are generally associated with the equigranular granite (Unit 3), either within the granite or within sedimentary rocks in the exocontact zone. Endogranitic mineralization most commonly consists of cassiterite, and lesser amounts of wolframite and molybdenite within greisen-bordered quartz veins, greisen lenses, miarolitic cavities, or stockworks of quartz±feldspar veins. Exogranitic mineralization typically occurs in quartz-vein swarms where wolframite is the most economically significant mineral (approaching economic grade at the Burnthill tungsten deposit) in association with cassiterite, scheelite, molybdenite, and/or base-metal sulphides.

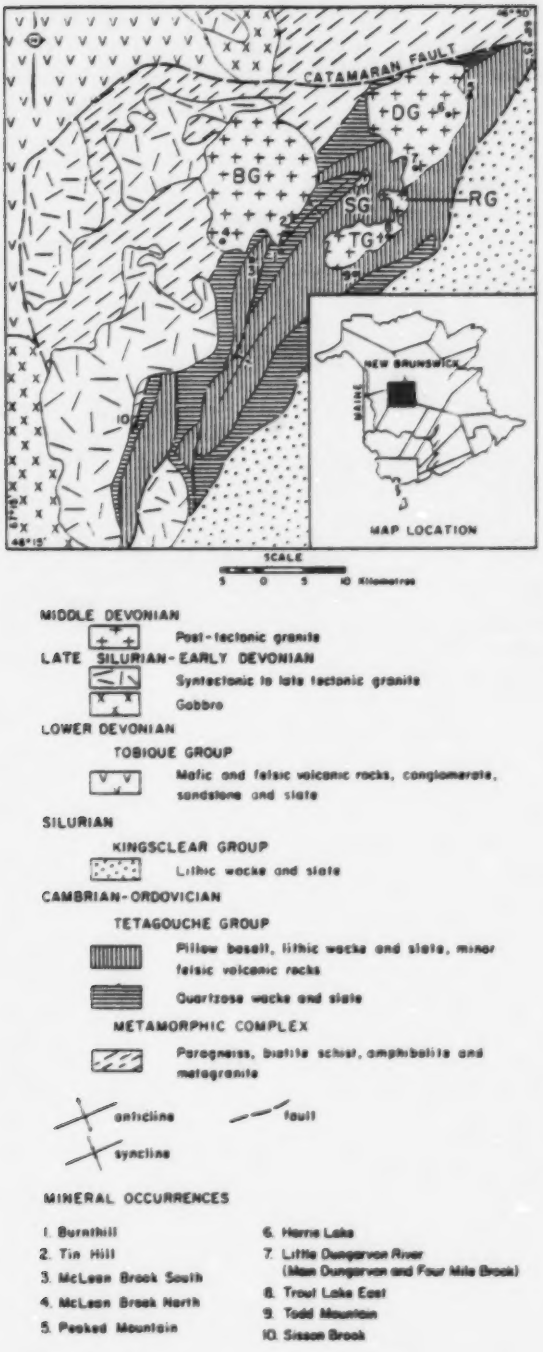

FIGURE 16. Geologic setting of granites in the Burnthill Brook area. BG = Burnthill Granite, DG = Dungarvon Granite, RG = Rocky Brook Granite, TG = Trout Lake granite, and SG = Sisters Brook Granite.

GEOCHEMISTRY

Several altered and mineralized samples were selected in 1987 for geochemical analysis in order to evaluate the metallic mineral potential of the Burnthill Brook area. The samples represent variously greisenized, feldspathized, and brecciated rock-types within the Middle Devonian plutons as well as quartz veins and silicified stockworks from the plutons and their surrounding country rocks. These analytical results have been recently published in Geoscience Report 88-1 (Fyffe and MacLellan 1988).

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GEOCHEMISTRY AND SULPHUR ISOTOPE COMPOSITIONS OF VEIN MINERALS FROM THE BURNTHILL GRANITE-RELATED TUNGSTEN DEPOSIT, CENTRAL NEW BRUNSWICK - MDA

H.E. MacLellan, R.P. Taylor, & H. Lyon

The Burnthill tungsten deposit is located approximately 105 km northeast of Fredericton within the Cambro-Ordovician quartzites and slates of the Tetagouche Group in the Miramichi terrane of central New Brunswick. The deposit consists of numerous (greater than 30), subparallel W-Sn-Mo-Be-F-bearing, fissure-filling quartz +/- topaz veins with local concentrations of Fe, Cu, and As sulphides, which straddle the contact between these metasediments and the Burnthill pluton. The vein minerals in relative order of decreasing abundance are: quartz, topaz, fluorite, pyrrhotite, wolframite, beryl, sphalerite, muscovite, molybdenite, chlorite, chalcopyrite, cassiterite, pyrite, arsenopyrite, apatite, scheelite, native bismuth, and galena. The main ore mineral, wolframite, occurs in two distinct associations: (1) quartz + topaz + wolframite +/- molybdenite; and (2) quartz + muscovite +/- topaz +/- wolframite. The wolframites have a range of compositions from Mn-rich ferberite to Fe-rich huebnerite (Table 1), although the Fe/Mn ratio averages 1.1/1. The Burnthill deposit wolframites have much lower Fe contents by comparison with wolframites from other granite-related deposits, both locally and regionally (Table 1). The Burnthill vein mineral paragenesis can be divided into three stages: (1) early oxide-silicate; (2) main sulphide; and (3) late chlorite. The eary oxide-silicate stage, represented by quartz, topaz, beryl, wolframite, muscovite, and fluorite with lesser amounts of cassiterite and molybdenite is economically and volumetrically the most important, and the presence of topaz and fluorite emphasizes the fluorine-rich nature of the hydrothermal fluid at this early stage of vein formation. Wolframite crystallized exclusively during this period; and quartz, one of the first minerals to form, occupies 45 to 95% of the vein volume. Minor, but geochemically significant, amounts of niobium (0.02 - 0.41%) and tantalum (up to 0.20%) substitute for tin in the cassiterite (Table 2) and reflect the elevated contents of these elements in the hydrothermal fluid at this stage; a feature that is also illustrated by the occurrence of the previously undescribed mineral pyrophanite (ideally $MnTiO_3$), a complex oxide of manganese, iron, and titanium, which in the Burnthill deposit contains greater than one per cent Nb.

The main sulphide stage, which clearly postdates the oxide-silicate stage, typically occupies less than 5% of the vein volume, and was initiated by the formation of arsenopyrite (Table 3). It is dominated by overlapping deposition of sphalerite, pyrrhotite, and chalcopyrite, with lesser amounts of pyrite and marcasite.

TABLE 1. · Wolframite compositions

	Burnthill deposit				McLean Br. N.	Mount Pleasant
	LD-13 (n=6)	BH-2 (n=7)	BH-2 (n=11)	ALD-1 (n=5)	85-132 (n=6)	MTP-1 (n=12)
	concentrations in weight percent					
FeO	11.86	9.16	11.06	12.27	15.68	20.66
MnO	11.79	14.69	12.70	11.33	8.38	2.86
WO_3	74.81	75.82	75.52	75.70	76.28	75.84
TOTAL	98.46	99.67	99.28	99.30	100.34	99.36

NOTE: number in parentheses is the number of electron microprobe analyses; na = not analysed.

TABLE 2. Cassiterite and Fe-Ti-oxide compositions

	Burnthill deposit		
	cassiterite		pyrophanite
	30-77.1 (n=6)	30-77.3 (n=3)	12-272 (n=4)
	concentrations in weight percent		
SnO_2	100.97	100.30	na
FeO	0.12	0.11	16.48
MnO	na	na	32.41
TiO_2	na	na	48.97
Nb_2O_5	0.14	0.19	1.61
Ta_2O_5	0.11	0.10	na
TOTAL	101.34	100.70	99.47

The abundance of sphalerite-pyrrhotite-chalcopyrite intergrowths demonstrates their intimate association, and exsolution textures of pyrrhotite +/- chalcopyrite in sphalerite are common. The style of sulphide precipitation can be divided into two classes: (1) open space and fracture filling between and within well-formed crystals of quartz, topaz, and wolframite; and (2) replacement (often pseudomorphic) of earlier formed minerals (e.g., scheelite pseudomorphed by pyrrhotite; topaz replaced by pyrrhotite and/or sphalerite). Quartz continued to precipitate in minor amounts throughout the main sulphide stage as evidenced by the occurrence of quartz veinlets cross-cutting sphalerite-pyrrhotite-chalcopyrite intergrowths, which had formed interstitially to earlier quartz and topaz.

Arsenopyrites from the Burnthill deposit have nearly ideal stoichiometry with atomic % Fe = 33.00, atomic % As = 32.79, atomic % S = 34.11 and very low contents of Co, Ni and Mn (Table 3). Geochemically the Burnthill arsenopyrites are almost identical to those from the McLean Brook North and South deposits (Table 3) and together these compositions yield temperatures in the range 490° to 460°C (cf., Kretschmar and Scott 1976) for arsenopyrite deposition in the three deposits. The pyrrhotites from the Burnthill deposit also have very low trace-element contents, in contrast to the sphalerites which contain small but significant amounts of manganese, copper, cadmium, and indium (Table 4).

The last stage of mineralization is dominated by a second generation of fluorite, radiating chlorite, and a final pulse of sericite. Fluorite, which shows cross-cutting relationships with many minerals of the oxide-silicate and main sulphide stages, is a vein mineral of substantial volume, contributing up to 10% in some samples. Chlorite and sericite show distinct cross-cutting relations and are clearly later than fluorite, making them amongst the last minerals to have been deposited. Calcite also constitutes a part of this last stage (cf., Potter 1969).

Sulphur isotope analyses of main sulphide stage minerals yield $d^{34}S$ values (in per mil relative to the Canon Diablo International Reference Standard) of circa 9.1 for arsenopyrite, 5.0 to 7.8 for pyrrhotite, and 5.3 to 6.7 for pyrite; and one pyrrhotite-pyrite mineral pair yields a sulphur isotope geothermometry temperature of 280°C using the fractionation factors of Ohmoto and Rye (1979). At temperatures in the range 280° -480°C, sulphur isotope values of this magnitude (i.e., 5.0 to 9.1 per mil) are commensurate with a magmatic derivation for the sulphur in the hydrothermal fluid.

Although the mineral deposits in the environs of the Burnthill pluton are hosted by both granitic and metasedimentary rocks and have a quite varied mineralogy (Potter 1969; MacLellan and Taylor 1988), the overall style of emplacement (in quartz fissure-vein systems) and mineral paragenesis (early oxide-silicate stage followed by a later sulphide stage) are

TABLE 3. Arsenopyrite compositions

	Burnthill deposit	McLean Br. North	McLean Br. South	
	32-208 (n=4)	85-132 (n=3)	MB-5 (n=5)	MB-5 (n=4)
	concentrations in weight percent			
As	44.78	44.81	45.26	45.58
Fe	33.60	33.56	34.38	34.24
Co	0.10	0.10	0.12	0.12
Mn	0.00	0.00	0.02	0.02
Ni	0.00	0.00	0.00	0.00
S	19.94	19.84	20.25	20.14
TOTAL	98.42	98.31	100.03	100.10
	atomic percent			
Fe	33.00	32.97	33.20	33.11
As	32.79	32.85	32.59	32.85
S	34.11	34.08	34.08	33.92

TABLE 4. Pyrrhotite and sphalerite compositions

	Burnthill deposit				
	pyrrhotite				sphalerite
	79-12 (n=7)	12-272 (n=4)	12-272 (n=4)	30-73.3 (n=3)	30-73.3 (n=3)
	concentrations in weight percent				
Mn	na	na	na	0.00	0.41
Fe	60.46	60.86	60.78	59.90	11.68
Co	0.00	0.01	0.01	0.02	na
Ni	0.02	0.00	0.00	0.03	na
Cu	0.00	0.00	0.00	0.00	0.26
Zn	0.01	0.03	0.02	na	52.26
Cd	na	na	na	na	0.41
In	na	na	na	na	0.55
Sn	0.01	0.00	0.00	na	na
S	39.33	39.02	39.27	39.22	33.48
TOTAL	99.83	99.92	100.08	99.17	99.05

similar. Together with the petrological and geochronological data (Taylor et al. 1987; MacLellan and Taylor 1988) these features suggest a close genetic tie between the emplacement of the Burnthill granite and the genesis of the spatially associated mineral deposits; this relationship is reinforced by the preliminary results of this current study which evidence: (1) the similarities that exist in mineral compositions at the oxide-silicate and sulphide stages in deposits of both endo- and exogranitic setting, (2) the elevated contents of incompatible elements (e.g., Nb) in vein minerals such as cassiterite, and (3) the likely magmatic derivation of sulphur in the hydrothermal fluid.

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BEDROCK GEOLOGY OF THE McADAM-ST. CROIX RIVER AREA

L.R. Fyffe, Senior Geologist

INTRODUCTION

The McAdam-St. Croix River area is located approximately 135 km southwest of Fredericton along the border between Maine and New Brunswick (Figure 17). The geology of three 1:20 000 scale maps (21 G/11c, d, and 21 G/6e) was completed this field season. The area is largely covered by a coniferous forest that generally takes the form of cedar swamps whose only redeeming value would appear to be the absence of alligators and poisonous snakes. Outcrops are restricted to the main highways, lumber roads, and the St. Croix and Canoose rivers. Because of the poor exposure, LANDSAT-MSS lineament trend maps were prepared (Geodat 1988a - f). However, the strong glacial overprinting in the area limits their application in regard to bedrock mapping.

STRATIGRAPHY AND STRUCTURE

A fault-bounded belt of Ordovician rocks (Unit Os), located in the northwest corner of 21 G/6e (Figure 17), trends from the St. Croix River northeasterly to Halls Brook. This unit comprises interstratified black pelites and light grey psammites, ranging from 1 to 30 cm in thickness. The severely contorted nature of these beds readily distinguishes them from younger rocks in the area.

The shallow dips of bedding in the Ordovician rocks are a consequence of tight recumbent folding and are in marked contrast to the steep attitudes in the adjacent Silurian strata to the northwest and southeast. The recumbent folds are deformed by more open, upright folds that plunge gently to the northeast. The cleavage, which is axial planar to these later folds, parallels the fold trend in Silurian rocks. The pelites and psammites possess a strong preferred orientation of micas indicating regional metamorphism in the greenschist facies. The Ordovician age for these rocks is assigned on the basis of their lithological and structural similarity to the lower Tetagouche Group of central New Brunswick.

The greater part of the McAdam-St. Croix River area is underlain by a thick clastic, dominantly turbiditic sequence deposited within the Silurian Fredericton Trough (McKerrow and Zeigler 1971). The turbidites (Unit Ss) can be divided into two lithological packages: very thick bedded (up to 1 m), medium-grained, quartzofeldspathic sandstone and minor dark grey slate to the northwest of the Norumbega-Fredericton fault zone (Figure 17); and fine- to medium-bedded, fine-grained calcareous sandstone, light green slate, dark grey pyritiferous slate, flaggy mica-rich sandstone, and thick-bedded, medium-grained, quartzofeldspathic sandstone to the southeast of the fault. Their detrital texture shows little evidence of recrystallization, suggesting subgreenschist regional metamorphism.

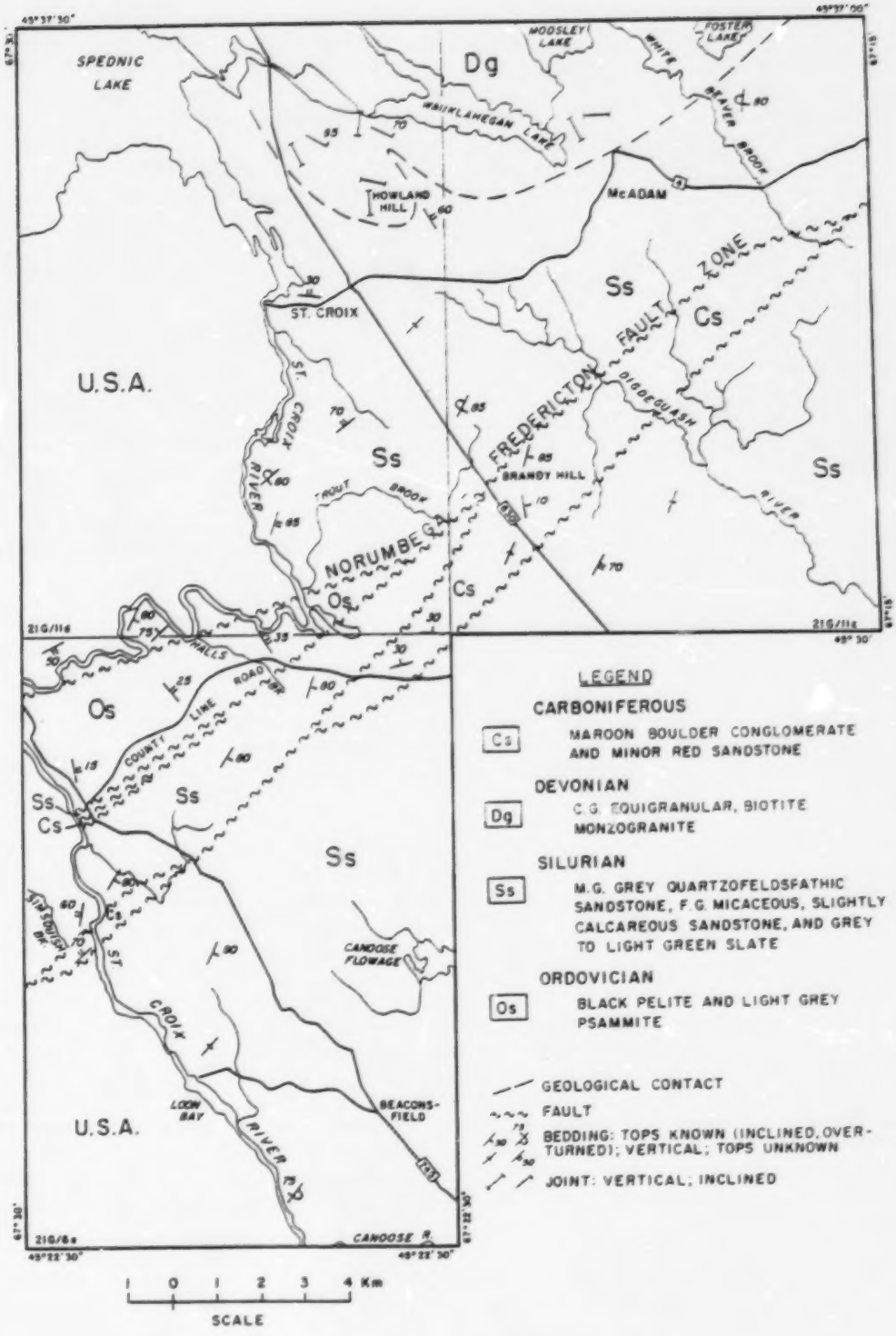

FIGURE 17. Geology of the McAdam-St. Croix River area.

No fossils have been recovered from the Fredericton Trough in southwestern New Brunswick. Ruitenberg and Ludman (1978) include the rocks of the McAdam-St. Croix River area in the Digdeguash Formation, but abundant black slate and granule conglomerate characteristic of that formation do not occur in the area. However, the turbidites in the southeastern part of the area, lithologically resemble the Flume Ridge Formation (Ruitenberg 1968), and the late Llandoverian to Wenlockian Waterville Formation in Maine (Osberg 1968). The Flume Ridge Formation overlies the Digdeguash Formation in the type area.

The thick-bedded turbidites in the northwestern part of the area do not resemble either the Digdeguash or Flume Ridge formations. However, they are similar to, and on strike with, the Vassalboro Formation in Maine (Osberg 1968), and the graptolite-bearing, Wenlockian to Ludlovian "Burtts Corner greywacke" (Berry and Boucot 1970) exposed on the Trans-Canada Highway west of Fredericton.

Bedding in the Silurian rocks strikes to the northeast with steep dips either to the northwest or southeast. Actual fold closures associated with the vertical axial planar slaty cleavage have not been observed, but the ubiquitous steep bedding attitudes suggest that the folds are tight. Bedding-cleavage intersections indicate that these folds plunge gently to the northeast. A later conjugate set of vertical kink folds can be seen in most exposures. The sinistral kink band has a strike of 90° and the dextral band, 130° indicative of shortening approximately parallel to bedding. Steep northeast-trending and subhorizontal kink folds have been observed locally.

The northern portion of the map area is underlain by the Early Devonian Pokiok granite batholith (Unit Dg). The granite is coarse grained, equigranular, and contains about 10% biotite. A fine-grained, quartz-feldspar porphyry dyke intrudes the granite on Howland Hill. Thermal effects of the granite, which include the growth of andalusite and biotite, can be recognized in the surrounding Silurian country rocks up to one kilometre from the contact. Veins of leucogranite transect the country rocks a few metres from the contact.

A narrow, fault-bounded, discontinuous belt of Carboniferous redbeds (Unit Cs) extends from the mouth of Simsquish Brook on the Maine side of the St. Croix River (21 G/6e) to just east of the Digdeguash River (21 G/11c). No fossils have been discovered in these rocks, so they could conceivably be as old as mid-Devonian.

Thick beds of maroon conglomerate, interstratified with rare red sandstone beds ranging from 1 to 6 cm in thickness, can be traced from the County Line Road northeastward beyond Brandy Hill on Highway 630. The conglomerate contains clasts of Silurian sandstone, milky quartz, maroon sandstone, and

minor black chert and mafic volcanic rocks. It forms beds from 20 cm to a metre and more in thickness, exhibits cut-and-fill structures, contains rounded clasts ranging from 3 to 15 cm in size, and is clast supported. These features are typical of a braided-stream environment. Pebble imbrication indicates a southward transportation direction. Very thick bedded conglomerate southwest of Brandy Hill, contains angular cobbles up to 25 cm in size and a greater proportion of matrix, and may represent debris flows at the head of an alluvial fan (C. St. Peter, personal communication, 1988).

The redbeds on Simsquish Brook, which apparently occur in a separate graben than that occupied by the conglomerate beds at Brandy Hill, are fine-grained, maroon quartzose sandstones interstratified with rare, coarse-grained arkosic beds about 15 cm thick. A highly sheared wedge of conglomerate is exposed on the St. Croix River about 2.5 km upstream from the mouth of Simsquish Brook.

FAULT TECTONICS

The Norumbega-Fredericton fault zone, which extends from eastern Maine to Fredericton (Ludman 1986), passes through the central region of the McAdam-St. Croix map area. This fault zone has a long history of dextral transcurrent motion (Unger et al. 1987). In the present map area, the counterclockwise orientation of slaty cleavage in Silurian rocks relative to the fault zone is consistent with dextral motion. This sense of displacement must have extended at least into the Middle Devonian since granite of that age is dextrally offset by a few hundred metres in Maine (Wones 1980). The transcurrent Norumbega-Fredericton fault zone may have been localized by pre-existing south-directed thrusts recognized in seismic profiles across southeastern Maine (Unger et al. 1987). Several major east-northeast-trending faults in the McAdam-St. Croix River area form part of the Norumbega-Fredericton fault zone. Evidence for the existence of these faults is described below.

Extensive quartz-flooding and brecciation are present near the northwestern boundary of the Ordovician rocks, along the west-flowing section of the St. Croix River. In addition, a sheared wedge of Carboniferous conglomerate occurs along the southeastern side of the Ordovician rocks. Therefore, the boundaries of the Ordovician rocks are interpreted to be faulted, even though the actual fault contacts are not exposed.

Another fault, extending from Simsquish Brook to Brandy Hill, is delineated by down-dropped Carboniferous redbeds within the Silurian sequence. The nature of this fault can be examined on Simsquish Brook where Carboniferous redbeds dip under Silurian sandstone and slate at an angle of 70° to the northwest. Evidently, high-angle reverse movement has taken place along the re-activated margin of the narrow graben into

which the redbeds were deposited. Just north of the confluence of Simsquish Brook on the St. Croix River, ramping of Silurian sandstone over slate within a steep shear indicates sinistral movement has also occurred along the same fault. This sense of displacement is supported by the regional change of bedding trends from northeasterly to northerly as the fault is approached.

Minor northeast-trending shears display evidence of dextral motion. This is shown by offsets of quartz veins and bedding planes in exposures on the St. Croix River 1 km south of Simsquish Brook (21 G/6e) and on a lumber road northwest of Trout Brook (21 G/11d). The z-shaped assymetry of a drag fold, exposed along a lumber road 2 km southeast of Brandy Hill (21 G/11c), is in agreement with dextral movement on the Norumbega-Fredericton fault zone.

In summary, the Norumbega-Fredericton fault zone represents a major transcurrent boundary along which Carboniferous sedimentary rocks were deposited in separate pull-apart grabens. Regional structural relationships are consistent with significant dextral motion during which a wedge of Ordovician rocks was emplaced along the fault zone. Locally, there is evidence for sinistral offset but its timing relative to the dextral movement is uncertain. However, a northeast-southwest principal stress orientation, indicated by the presence of late conjugate kink folds, may have produced an episode of sinistral motion following a period of dextral movement.

ECONOMIC GEOLOGY

Quartz veins are present in most exposures of Silurian rocks in the map area. These veins occur in various orientations, but most commonly trend parallel to bedding. Some are folded and must have been emplaced during or prior to the main deformational event in these rocks. Quartz veining is particularly abundant in the many northeast-trending shear zones throughout the area. Samples of the veined sedimentary rocks have been collected and will be assayed for gold.

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QUATERNARY GEOLOGY AND TILL GEOCHEMISTRY IN NORTHERN NEW BRUNSWICK

A.G. Pronk and M.A. Parkhill

The 1:50 000 scale surficial mapping and till sampling at one sample per 4 km^2 continued this summer in the Riley Brook area (21 O/3). Similarities in geological setting of the study area and the previously investigated Upsalquitch Forks area with its known gold occurrences made Riley Brook a logical "next" (Figure 18). Simultaneously, Reg Wilson (this volume) continued bedrock mapping and the Geological Survey of Canada carried out a detailed stream sediment survey in the same area (Peter Friske, personal communication, 1988). These data sets will give ongoing exploration a solid working base.

The glacial history of the area is quite different from the previous study areas and this is mainly the result of the configuration of the Gaspésie, the northern New Brunswick highlands and the Saint John River valley in an area that was influenced by continental and local ice masses.

Rappol (1988) reported due east ice-flow from Maine in the dispersal of Debouille syenites as an early flow phase. Granites from northern Maine are also found in the western half of the study area (west of the Tobique River) as a result of the same flow. Granites and anorthosites from the Canadian Shield were also found in this area, implicating a southeastward flow into the area. Ice obviously crossed the Laurentian Channel, flowing into northern Maine and northwestern New Brunswick, but did not cross into the Chaleur Bay area.

Two corresponding sets of striae were recorded in the eastern part of the study area; an early eastward flow (090-120°) and a later southeastward flow (110-150°). Locally, these were followed by north and southward flowing ice. Till pebble lithologies and distribution of a red till eastward of the Carboniferous inlier indicate mostly eastward transport. The red till can be found up to 15 km east of its source. A detailed surficial geology map with till geochemistry data is presently being prepared for release early next summer.

In the wake of the discovery of epithermal gold at Rocky Brook and the Jacquet River trend (Burton 1988) a comparison was made between Au, Ag, As, Sb and Hg in tills for map areas 21 O/9, O/10, and O/15. The correlation matrix for these elements for map sheet 21 O/15 indicates there is no strong mathematical correlation for Au and any of its pathfinders.

The areal distribution of Au with Hg and Ag reveals a crude regional pattern (see Figures 19 and 20). As and Sb locally

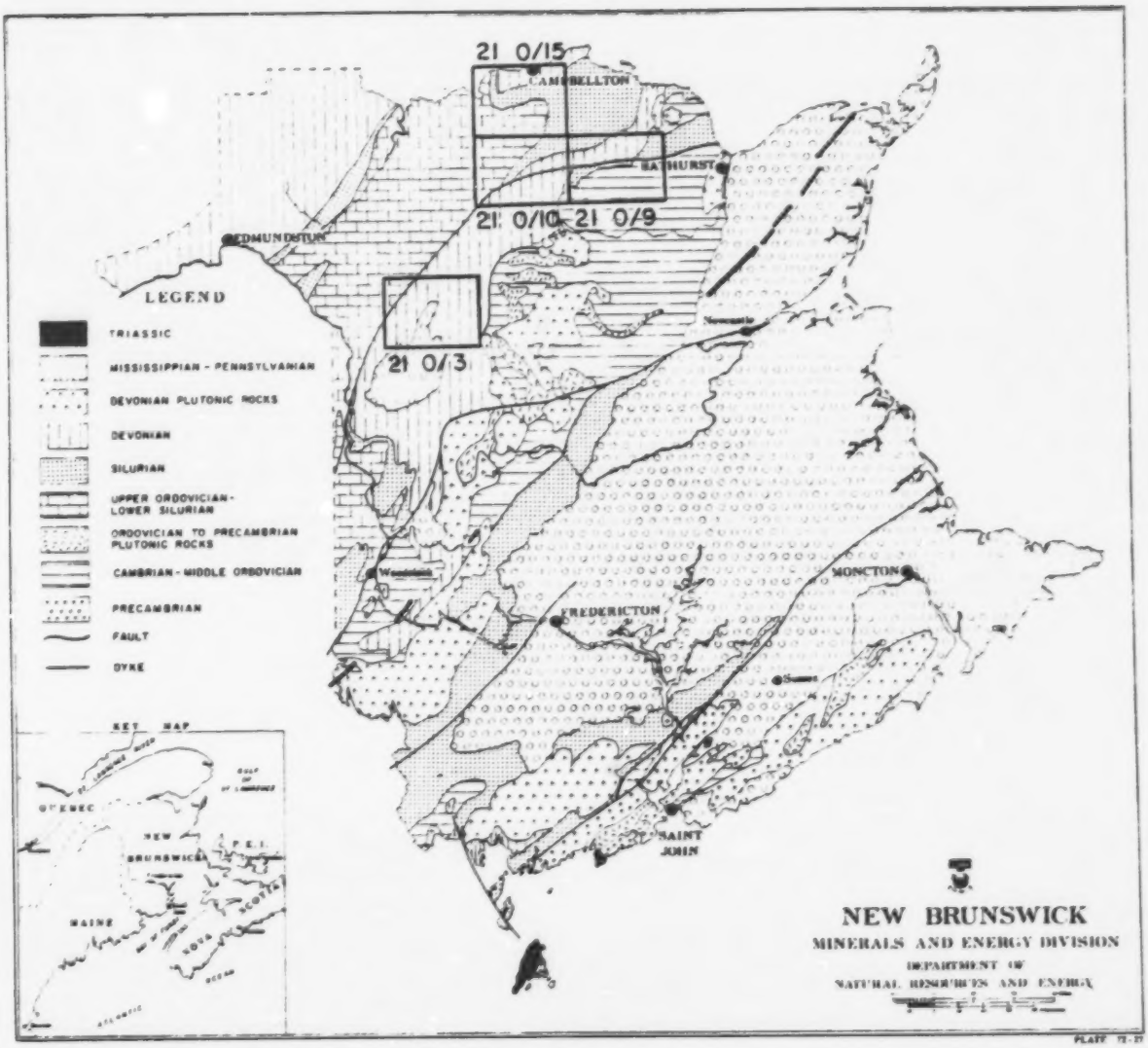

FIGURE 18. Index map to the study areas.

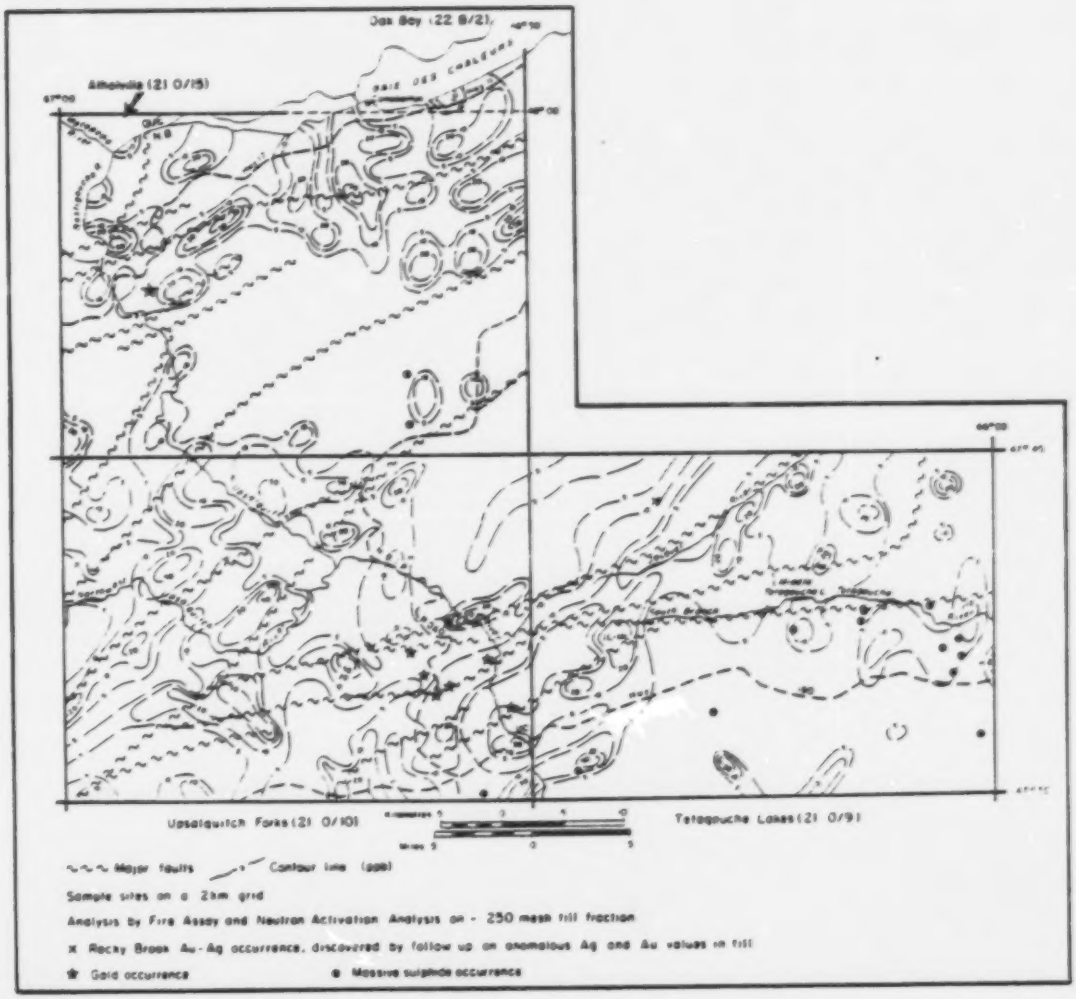
Jos Bay (22 B/2)
Athelvale (21 O/15)
Upsalquitch Forks (21 O/10)
Tetagouche Lakes (21 O/9)
Major faults
Contour line (ppb)
Sample sites on a 2km grid
Analysis by Fire Assay and Neutron Activation Analysis on - 250 mesh till fraction
x Rocky Brook Au-Ag occurrence, discovered by follow up on anomalous Ag and Au values in till
Gold occurrence
Massive sulphide occurrence

FIGURE 19. Au in tills of 21 O/9, O/10, and O/15.

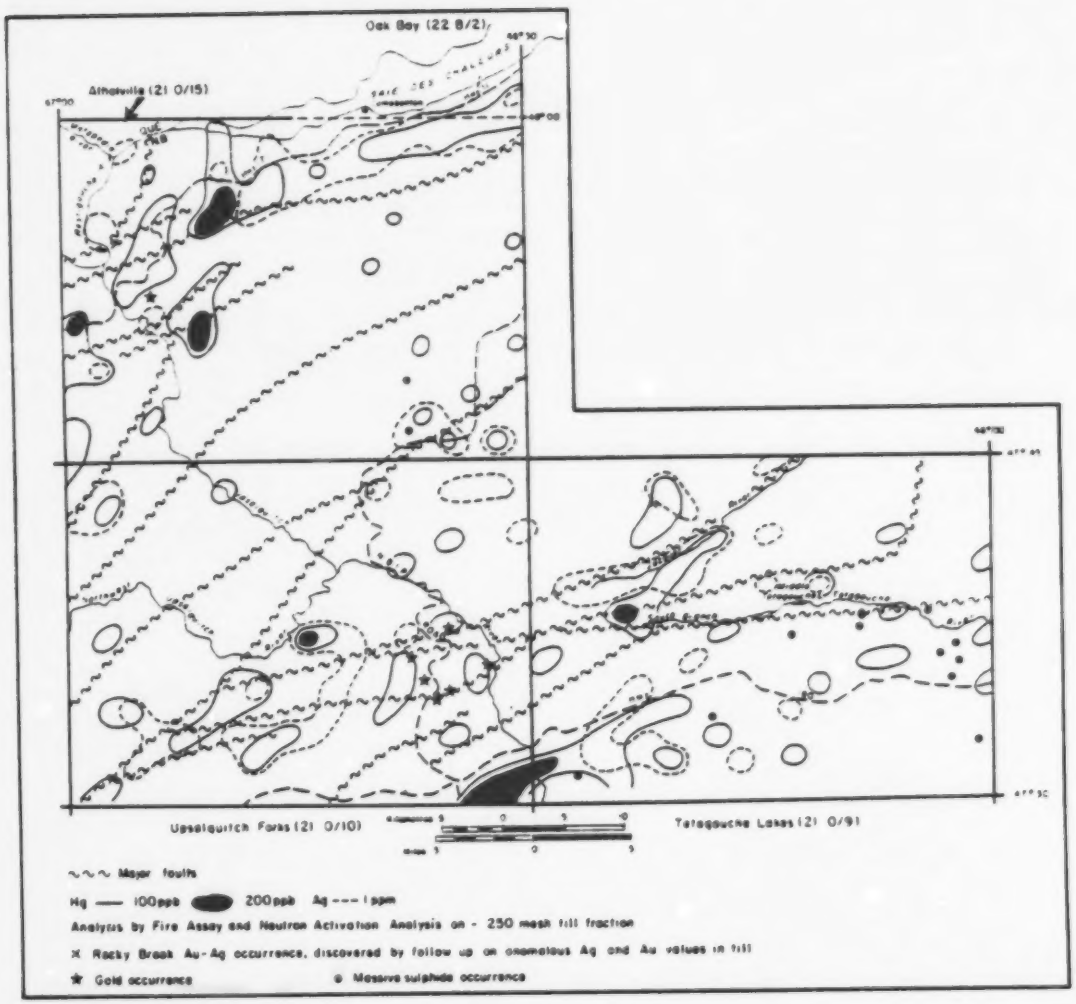
Oak Bay (22 B/2)
Athotville (21 O/15)
Upsalquitch Forks (21 O/10)
Tetagouche Lakes (21 O/9)
Major faults
Hg —— 100ppb 200ppb Ag --- 1ppm
Analysis by Fire Assay and Neutron Activation Analysis on - 250 mesh till fraction
Rocky Brook Au-Ag occurrence, discovered by follow up on anomalous Ag and Au values in till
Gold occurrence
Massive sulphide occurrence

FIGURE 20. Hg and Ag in tills of 21 O/9, O/10, and O/15.

strengthen this pattern, and although associated with each other, do not show strong correlation with the other elements. This pattern is present along the Jacquet River (see also Burton 1988), the Rocky Brook-Millstream main break, along the northwest Upsalquitch River toward the Restigouche River, parallel to the south shore of the Chaleur Bay and possibly joins up in the east with the Jacquet River trend described by Burton (1988).

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RILEY BROOK PROJECT

R.A. Wilson

Detailed geological mapping of the Riley Brook (east) sheet (NTS 21 O/3E) began in the summer of 1988 and is in progress. Preliminary mapping indicates an intimately interbedded succession of felsic, mafic, and lesser intermediate tuffs and flows, and sedimentary rocks (quartzose sandstone, siltstone, slate). All the rocks in the area belong to the Lower Devonian Tobique Group, which underlies most of the Tobique subzone of the Chaleur Bay Synclinorium.

There is a substantial variation within individual map units, both in terms of their lithology and in their stratigraphic thickness and linear extent. Sedimentary rocks comprise areally extensive mappable units, and are commonly present as relatively thin interbeds within mafic or felsic rock units, facilitating the interpretation of the structure in these areas. Bedding attitudes in sedimentary rocks indicate a number of folds, although the role of folding in accounting for the observed distribution of the various map units (i.e., structural repetition of beds) is unclear as yet.

Mafic volcanic rocks include massive to vesicular andesitic to basaltic flows, basaltic ash or lapilli tuffs, and local pillow basalt.

Felsic volcanic units are typically lenticular in shape and pinch out along strike rather than forming long belts of relatively constant thickness. Massive and aphanitic rhyolites, comprising a significant proportion of these map units, probably represent rhyolite domes. In contrast, felsic pyroclastic rocks, mainly ash flows and ash-and-lapilli tuffs, can be mapped out in more elongate belts. It is possible that the rapid pinching out of some of the felsic units coincides with fold closures. Probable subvolcanic feeder pipes for some of the felsic volcanic units are preserved at Haystack Mountain and Bald Peak, which form very resistant, inverted-cone-shaped prominences consisting of fine-grained porphyritic igneous rock. Local exposures of feldspar porphyry are also believed to be shallow plutonic equivalents of some extrusive felsic rocks.

The presence of local orthoclase-horneblende syenitic intrusive rocks implies that some of the extrusive rocks may be alkali varieties (e.g., trachytes). Airborne magnetic highs over some felsic volcanic map units support this hypothesis, as these alkaline rocks are typically relatively high in iron; chemical analyses and petrographic examinations will establish whether this is the case.

Two generations of mafic intrusive rocks are present: one suite appears to be contemporaneous with volcanic activity and therefore represents feeders for the mafic extrusive rocks, whereas a later suite includes post-Acadian dykes and small stocks. Whole-rock chemical analysis will be employed to help confirm this interpretation.

Faulting has played some role in locally offsetting or terminating rock units: at least three east-southeast-, west-northwest-trending faults have been defined by lithological and aeromagnetic discontinuities and topographic linears.

In conjunction with the geological mapping, lithogeochemical analysis of all altered, brecciated, and/or mineralized rocks is being carried out. Several samples of felsic volcanic rocks showing some of the characteristics typical of an epithermal environment, have been identified and collected for multi-element analysis. These rocks are typically bleached, limonitic and hematitic (along fractures), pyritiferous, and/or silicified along cross-cutting microveinlets. These features are most often observed in narrow horizons within pink to buff rhyolite. Pyrite and base-metal mineralization and locally strongly altered or bleached horizons have been observed in several instances within an extremely hard (silicified?) grey rhyolite, and in silicified siltstone.

MINERAL DEPOSIT INVENTORY

R.R. Irrinki, Mineral Deposits Geologist

The comprehensive study of base-metal deposits in northern New Brunswick has been extended to include all the major metallic mineral deposits in New Brunswick. The purpose of the project is to update the available geological information on mineral deposits. These computerized data bases will be used by the Province to more effectively manage the mineral resources of New Brunswick. Several companies have been actively involved in compiling the data, which will be confidential except to provincial government employees and to the owners of the deposit.

Several massive sulphide deposits (Davies 1977) have been found in northern New Brunswick (Figure 21). Extensive work has been done by various companies on these deposits. Geological Surveys Branch geologists have prepared confidential reports on the Stratmat (1) and Key Anacon (2) deposits. Work on the Halfmile Lake (3) deposit is in the final stages of completion. Compilation of the Murray Brook (4) deposit is in progress.

Three gold deposits (5, Cape Spencer, owned by Gordex Minerals Limited; 6, Millican Lake, owned by Mispec Resources Inc.; 7, Alcida, owned by Lacana Mining Corporation) have been discovered in the last few years. All available data has been entered into the computer. Manipulation of the data on the Alcida deposit is completed and work on Millican Lake and Cape Spencer is in progress.

The data on approximately 500 drill holes from the Lake George (8) deposit have been entered into the computer. Detailed analysis of the data will be carried out in the coming year. Data from the Burnthill (9) deposit drill holes have also been entered.

REFERENCE

DAVIES, J.L. 1977. Geological map of northern New Brunswick. New Brunswick Department of Natural Resources, Mineral Resources Branch, Map NR-3.

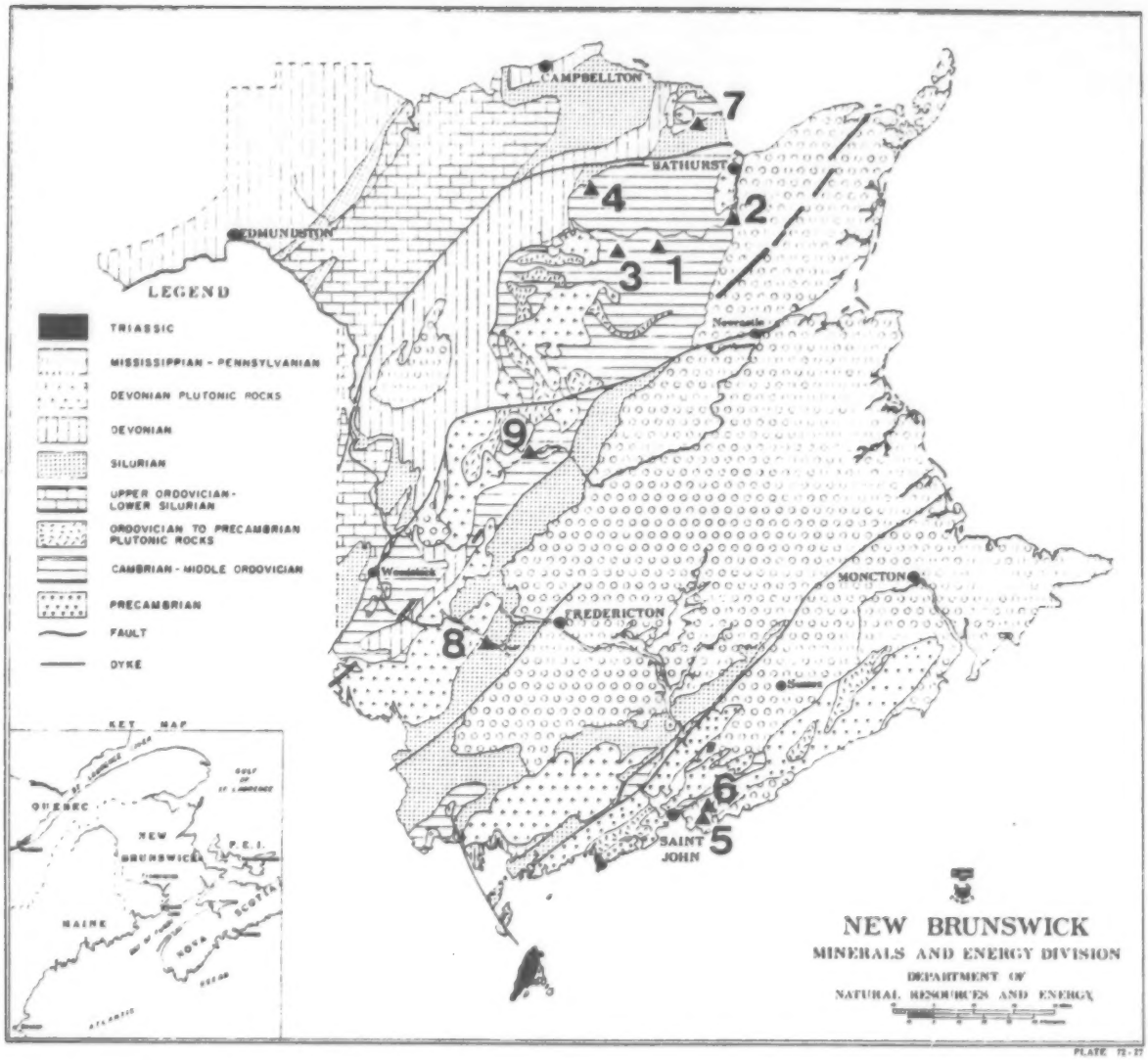


FIGURE 21. Mineral deposit inventory - 1988. (1) Stratmat, (2) Key Anacon, (3) Halfmile Lake, (4) Murray Brook, (5) Cape Spencer, (6) Millican Lake, (7) Alcida, (8) Lake George, and (9) Burnthill.

GEOCHEMISTRY LABORATORY

L.R. Fyffe, Senior Geologist

The present laboratory located at the Soils and Minerals Building on College Hill Road is equipped to analyse Cu, Pb, Zn, Ag, Ni, Co, Fe, and Mn by atomic absorption spectrometry and Sb, W, V, and Mo by various colorimetric methods. The laboratory is staffed by one supervisor (Mrs. Valeria Rinco) and an assistant (Mrs. Bettina Edney).

The role of the geochemical laboratory has been undergoing review by the Division prior to its relocation to new facilities in the Hugh John Flemming complex. Suggestions as to the future utilization of the new laboratory have also been solicited from consultants C.F. Gleeson and Associates Ltd. and are summarized below.

The hiring of a professional geochemist to oversee the operations of the laboratory and field surveys is a foremost requirement. This position has recently been filled.

It is recommended that the present analytical capability of the laboratory be maintained with some changes in digestion methods and corrections for background interference. Analysis for precious metals and multi-element packages are most economically done commercially.

It will be the responsibility of the Minerals and Energy Division to monitor the quality of the results obtained from commercial laboratories by inserting standards and duplicate samples. This can best be accomplished if the Division has its own sample preparation equipment. By carrying out the sample preparation, the geochemical laboratory will have full control over the quality of the preparation procedures and the quantity of material prepared.

In addition to sieving, the laboratory will be equipped to handle rock preparation and heavy-mineral separations. For rock preparation the laboratory will acquire crushers (jaw and cone), pulverizers (plate-type and shatter-box type), stainless steel screens, and splitters. To prevent contamination from metals such as Fe, Cr, Ni and W, non-metallic pulverizers (i.e., porcelain plates and discs instead of steel) will be used. For mineral separations, a shaking table will be purchased along with the necessary heavy liquids and fume hoods.

To date, 1600 Carboniferous drilling chip samples have been pulverized at the Soils and Minerals Laboratory; 484 samples have been analysed for molybdenum, and 794 for vanadium. Approximately 4200 samples remain to be analysed by colorimetric methods, and 4475 samples to be analysed by Atomic Absorption.

In addition, 583 samples were analysed for Toon Pronk. Eight elements (Cu, Pb, Zn, Mn, Fe, Co, Ni, Ag) were analysed by atomic absorption after hot HNO_3 digestion. Mo and Sb were analysed colorimetrically. All samples were sent to Chemex Labs in Vancouver to obtain analyses of Au, Bi, Hg, Sb, and As. W and V will be tested colorimetrically.

A further 144 samples collected by Paul Chiswell will be analysed for the same suite of elements.

QUATERNARY STRATIGRAPHY OF SOUTHERN NEW BRUNSWICK

A.A. Seaman, Quaternary Geologist

INTRODUCTION

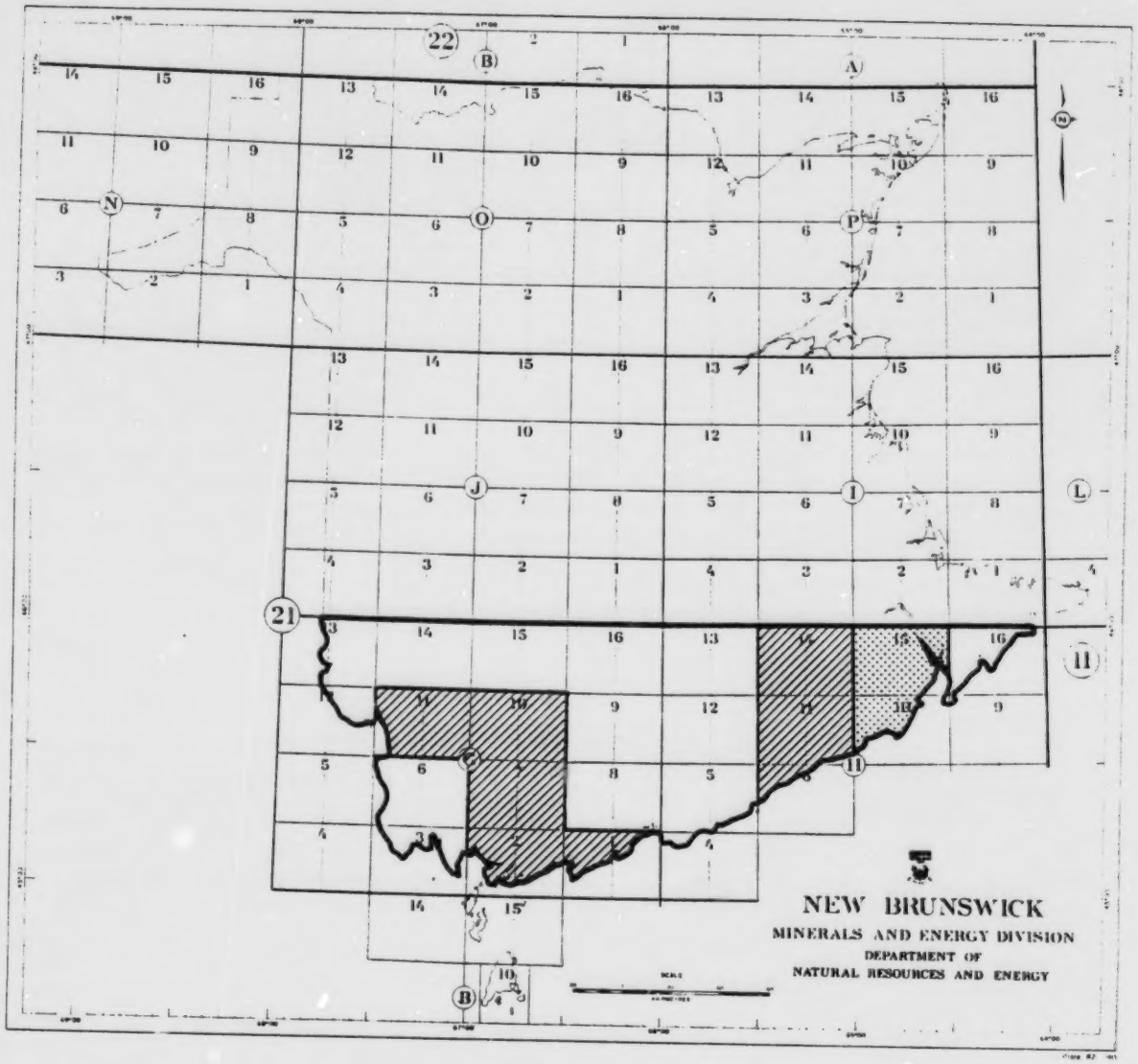
This year saw the commencement of a multi-year project to examine the glacial deposits and ice-flow indicators of southern New Brunswick (NTS 1:250 000 scale map sheets 21 G and 21 H; Figure 22). The literature on the Quaternary geology of this area indicates that it was subjected to a complex sequence of glacial events. Ice-flow directions ranging clockwise from northwestward through to southwestward have been reported from various parts of the area. The age of, and chronological relationships between, the various ice-flow events are poorly understood. In addition, the ice-flow events responsible for till deposition are largely unknown. Since till is one of the primary sample media used for mineral exploration in glaciated terrane, this state of affairs constitutes a significant hindrance to successful exploration. Consequently, the objectives of this project are to determine the chronological relationships between the differing ice-flow events; the till sheet, if any, associated with each event; and the physical and chemical characteristics of each individual till sheet.

FIELD WORK

Field work this year was concentrated in two areas (Figure 22): 1) a corridor across the Caledonian Highlands and onto the New Brunswick lowlands, primarily NTS map areas 21 H/6, H/11, and H/14; and 2) a corridor across the St. Croix Highlands and onto the New Brunswick lowlands, primarily NTS map areas 21 G/1, G/2, G/7, G/10, and G/11. Field work involved examination and description of stratigraphic sections; examination of bedrock outcrops exhibiting multiple glacial striae orientations; and description, sampling, and till fabric analysis at selected till exposures.

PRELIMINARY RESULTS

1) Rampton et al. (1984) postulated that the Caledonian Highlands were not glaciated during the Late Wisconsinan glaciation. However, comparison of soil profiles on tills in this area with those on tills in the New Brunswick lowlands indicates that the depth of soil development is identical in both areas. Preliminary till fabric results suggest that these highlands may actually have supported a late-stage ice cap. Till-fabric orientations, in general, diverge significantly from the main ice flows recorded by striae. Much of the till may have been deposited by east- or west-flowing ice.



project area

primary study areas, A.A. Seaman

study area, M. Foisy and G. Prichonnet

FIGURE 22. Index map: quaternary stratigraphy of southern New Brunswick, 1988.

2) In southwestern New Brunswick, ice flow appears, in general, to have rotated from southward through to eastward. As in the Caledonian Highlands, the main striae orientation appears to be a poor predictor of the ice-flow direction at the time of till deposition.

REFERENCE

RAMPTON, V.N., GAUTHIER, R.C., THIBAULT, J., and SEAMAN, A.A. 1984. Quaternary Geology of New Brunswick. Geological Survey of Canada, Memoir 416, 77 p.

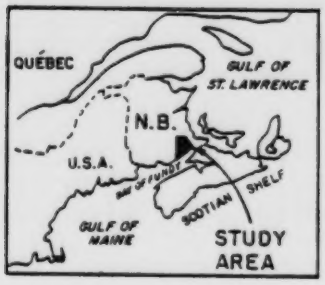
GLACIATION AND DEGLACIATION IN THE NORTHEASTERN PART OF THE CALEDONIAN HIGHLANDS, NEW BRUNSWICK - GLACIAL DISPERSAL AND MINERAL GEOCHEMISTRY OF TILLS

Foisy, Marc et Prichonnet, Gilbert
Département des Sciences de la Terre
Université du Québec à Montréal

The study, which began during 1987, continued during 1988 with the financial support of the New Brunswick Department of Natural Resources and Energy. The objective of the study is the recognition of the Quaternary paleogeography in the northeastern part of the Caledonian Highlands (Figure 23) and the surrounding areas (Foisy, in preparation). The project also includes the mapping of Quaternary deposits in Albert County (NTS 21 H/10 and 21 H/15). Systematic sampling of tills for geochemical analysis, aided by backhoe excavations, was also undertaken.

The igneous rocks of the Caledonian Highlands (Precambrian to Devonian) form a highland plateau with steep flanks, and are surrounded by Carboniferous sedimentary rocks. Based on micro-erosional features (137 sites), it is possible to reconstruct the following glacial ice-flow patterns: a) on the northern flank of the Caledonian Highlands: N350°?, N165°, N120°, N060°, and N030°; b) on the eastern and southern flanks: N140°, N180°, N220°, and N090°. Several sections on the southern and northern flanks of the plateau expose multiple tills. Till-pebble content and fabric analysis at 3 exposures on the north side of the mountains (Rosevale, Stoney Creek, and Parkindale) identify 3 or 4 till sheets related to 3 successive ice flows: firstly, toward the S and the SE; then to the ESE; and finally to the NNE. The sections on the southern flanks of the Highlands (North River and Harvey Bank) display a lower till, with a fabric to the SE, and then to the ESE, and an upper till with a distinct fabric to the SW. On top of the plateau, the till sheet has textures, fabrics, and pebble contents which are very similar to those in the upper till on the flanks. Well-preserved glaciofluvial accumulations and minor moraines are commonly observed in this area. These data seem to demonstrate the glaciation of the Caledonian Highlands during the Upper Wisconsinan: the nunatak hypothesis (Rampton et al. 1984; p. 38) is no longer useful and should not be retained for this part of the Caledonian Highlands.

In the upper till at Rosevale, igneous pebbles from the plateau, and dark shale debris from the Albert Formation (located along the northern edge of the plateau), identify a late northward ice-flow event. Limestone boulders from the Albert Mines - Hillsborough synclines have been recognized a few kilometres to the SSW of the outcrop areas, suggesting, in this case, a southwestward ice flow. Finally, sandstone and



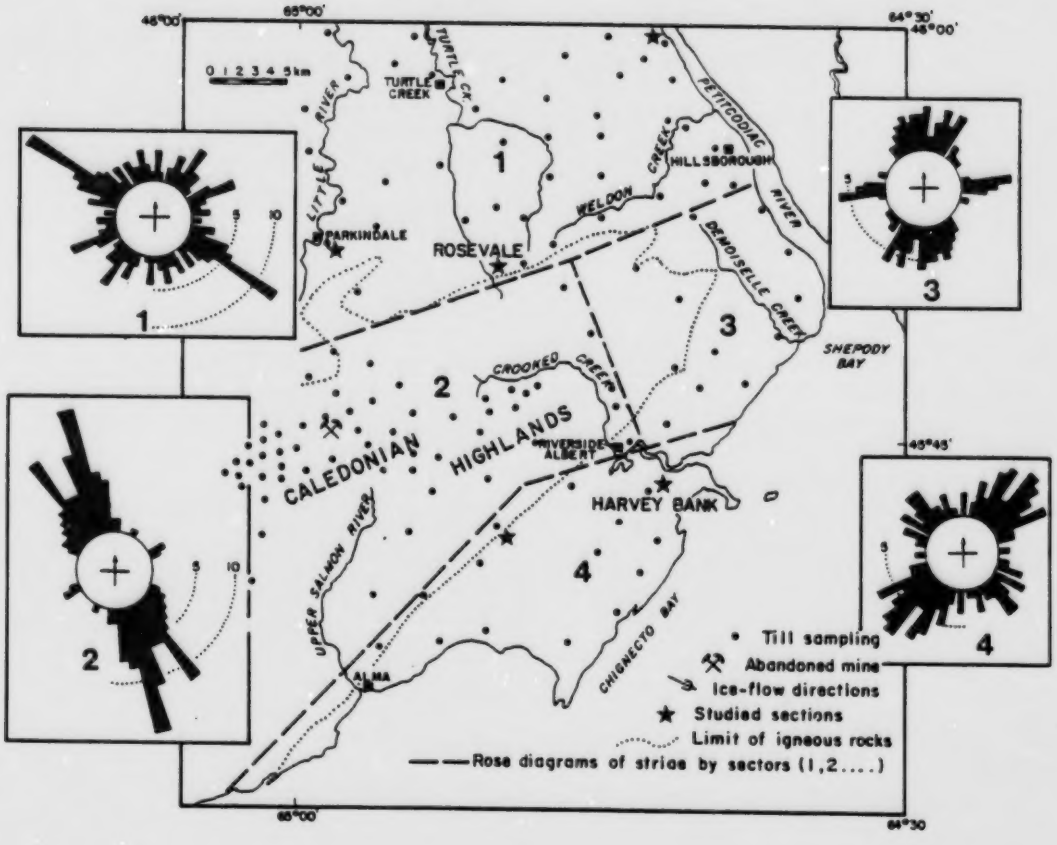


FIGURE 23. Location map and striae trends, northern Caledonian Highlands.

conglomerate clasts from the Parkindale - Turtle Creek area were commonly observed on the Caledonian Highlands; this evidence confirms that the entire area was glaciated during the last glacial event.

The detailed mapping conducted during this study will provide improved definition of the granular aggregate resources of the area (particularly ice-contact deposits). In addition, this research will provide further information on the regional Quaternary stratigraphy of the area.

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DRILL-CORE MANAGEMENT PROGRAM

G. Crouse, Core Manager

Approximately 10 000 metres of drill core was collected by the Department of Natural Resources and Energy this year. Most of the core was delivered to the Madran storage facility northwest of Bathurst.

Storage sheds are being constructed with MDA funds to house the surplus core at the Madran storage facility. It is hoped that 20 sheds will be completed by the end of the building season with each shed being able to hold approximately 10 000 metres of core.

Also with MDA funds, core-cutting saws were purchased to facilitate the sampling of drill core. There have been numerous requests for samples of drill core stored by the Province.

A new core-storage facility capable of storing approximately 80 000 m of core has been constructed as part of the Hugh John Flemming Complex. The facility has core-sampling equipment and has a large natural-light viewing room to observe the core.

The DNRE drill-core data base is still being appended.

MINERAL EXPLORATION STIMULATION PROGRAM (MESP)

G. Crouse, MESP Coordinator

MESP provides financial assistance to mineral exploration companies and prospectors who would like to carry out exploration for minerals within the Province of New Brunswick.

MESP is a direct private sector assistance program offered by the Department of Natural Resources and Energy over a one-year period commencing April 1, 1988. The main objective of the program is to promote exploration for the Province's hidden mineral resources.

A committee of government and private sector representatives reviews applications for MESP grants and, if approved, up to $10 000.00 per project is available. The committee members are R.R. Irrinki, L.R. Fyffe, A.A. Ruitenberg, S.R. McCutcheon, D. Hoy, and G. Crouse. Eligible work would include: regional and detailed prospecting, grid establishment, geological mapping, geophysical and geochemical surveys, trenching and drilling, assays and chemical analysis, and specialized work such as mineralogy.

Originally a total of $150 000.00 in provincial funding was allocated to MESP for the period April 1, 1988 to March 31, 1989 but the program was so popular that these funds were soon depleted and another $50 000 was allocated.

The committee reviewed applications for 48 projects, 31 of which were approved. A total of $396 035 was requested and $199 738 approved.

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FYFFE, L.R., and MacLELLAN, H.E. 1988. Lithogeochemistry (including gold) of altered and mineralized samples from the Burnthill Brook area (NTS 21 J/10) of central New Brunswick. New Brunswick Department of Natural Resources and Energy, Minerals and Energy Division, Geoscience Report 88-1, 92 p.

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WILSON, R.A. 1988. Preliminary geology and lithogeochemistry of selected rock samples, Riley Brook map area, east half (NTS 21 O/3E), Victoria County, New Brunswick. New Brunswick Department of Natural Resources and Energy, Minerals and Energy Division, Geological Notes Series PM 88-43, 24 p.

GEOLOGICAL SURVEYS BRANCH

GEOSCIENTIFIC DATA SECTION

GEOSCIENTIFIC DATA SECTION - 1988 ACTIVITIES

D.J.J. Carroll, Coordinator

The Geoscientific Data Section of the Geological Surveys Branch is responsible for providing a variety of geoscientific, technical, and support services to the staff of the Minerals and Energy Division. In addition, the staff of the Geoscientific Data Section provide assistance to the public and mineral exploration industry, in particular, by supplying hardcopy publication material on the geology and mineral resources of the province.

The Geoscientific Data Section is made up of three units; Geoscientific Editorial Services, Geoscientific Cartographic Services, and Geoscientific Information Services (Figure 24).

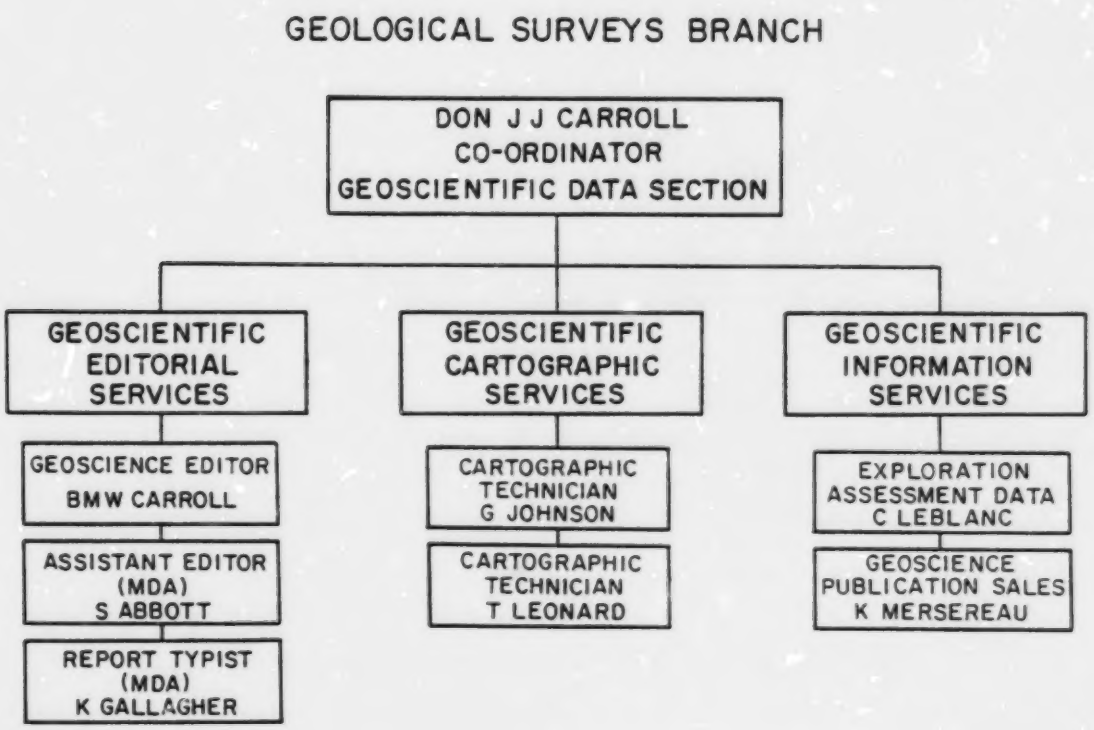

FIGURE 24. Organization chart for Geoscientific Data Section.

The total provincial budget for the Section in 1988 is $237 400.00, of which 26% is operating cost. Under the Canada-New Brunswick MDA (1984-89), the Geoscientific Data Section is responsible for Public Awareness, Information, and the Administration portion of the Mineral Development Agreement. Funding associated with this program for the fiscal year 1987-88 is $78 000.00.

A brief synopsis of activities carried out in 1988 by the Geoscientific Data Section is described below. In addition, the following includes information on Public Awareness projects carried out under the Canada-New Brunswick MDA (1984-89) by the federal government; Energy, Mines and Resources Canada, Communications Branch.

GEOSCIENTIFIC EDITORIAL SERVICES

The responsibility of this unit is to edit all geoscientific reports and maps that are produced by or for the Minerals and Energy Division. In 1988, the staff of this unit have edited and/or prepared for publication 39 reports and 99 maps. The following is a list of these reports:

GENERAL DEVELOPMENT AGREEMENT

HENDERSON, R.E., and KEYS, D. 1988. A detailed guide to computerized peatland inventory data files for New Brunswick. New Brunswick Department of Natural Resources and Energy, Minerals and Energy Division, Open File Report 83-11, 252 p.

MINERAL DEVELOPMENT AGREEMENT

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SNC INC. in collaboration with The Daniels Company. 1988. Beneficiation potential of Eastern Canadian coals: executive summary. New Brunswick Department of Natural Resources and Energy, Minerals and Energy Division, Open File Report 88-13, 22 p.

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MINERAL EXPLORATION ASSESSMENT REPORTS

Since the beginning of the calendar year, the Mineral Lands Section of the Mineral Development Branch has received 95 assessment reports from the mineral exploration industry. These reports consist of 54 public files and 41 reports that are to be held with a confidential status for a maximum period of two years. The majority of these reports have been indexed and are included in the Geological Survey of Canada's bibliographic data base called **GEOSCAN.**

The Geoscientific Data Section is continuing to microfilm all incoming assessment reports that are available at this time. Duplicate microfiche copies are placed in our Bathurst and Sussex regional offices as well as selected public libraries across the Province.

As part of the continuing efforts of the Geoscientific Data Section to inform mineral explorationists about the incoming assessment file reports, GEOSCAN bibliographic indexes are periodically produced and distributed.

In 1988, two GEOSCAN indexes were produced; one relating to reports submitted in the period 1987-88 up to March, and the second, a custom index of references to Gold in New Brunswick.

A more comprehensive GEOSCAN index to the 1987-88 assessment reports will be produced for distribution at the Thirteenth Annual Review of Activities.

GEOSCIENTIFIC PUBLICATIONS

The Geoscientific Information Services unit of the Geoscientific Data Section plays an important role in the

dissemination of geoscientific data to the mineral exploration industry in particular, but also to engineers, consultants, and the general public. Since the beginning of 1988, 45 reports and 230 maps have been added to our Supplementary List of Publications. A total of 763 specific requests for information resulted in the distribution of 6248 documents.

The Geoscientific Data Section prepares a publication notice listing the new publications that are available from the Minerals and Energy Division (including MDA publications from the Division and the Geological Survey of Canada). In 1988, this Section was involved in the preparation of 13 general and confidential publication releases. These releases were as follows:

1.	DNRE January/88	General publication release notice.
2.	DNRE March/88	General publication release notice.
3.	DNRE May 25/88	Surficial geology and till geochemistry of Atholville (21 O/15) and Escuminac (22 B/01) and Oak Bay (22 B/02) map areas.
4.	DNRE June 14/88	Lithogeochemistry (including gold) of altered and mineralized samples from the Burnthill Brook area (21 J/10 and 15) of central New Brunswick. Arsenic, antimony, barium and gold content of stream and spring sediments: Napadogan, west half (21 J/7W), Hayesville, east half (21 J/10E), Hayesville, west half (21 J/10W), Juniper, east half (21 J/11E), Plaster Rock, east half (21 J/14E), Tuadook Lake, east half (21 J/15E), Coldstream, west half (21 J/6W), Coldstream, east half (21 J/6E).
5.	DNRE June 23/88	Till geochemistry and surficial geology of the Rollingdam map area (21 J/6E).
6.	GSC June 30/88	High resolution aeromagnetic total field and vertical gradiometer surveys. 21 O/1E & W, 21 O/2E, 21 O/7E & W, 21 O/8W, 21 O/10E & W, 21 P/4W.

7.	GSC July 27/88	Airborne Gamma-Ray Spectrometer Survey, Woodstock-Fredericton area, New Brunswick. 21 G/3, 5, 6, 10, 11, 12, 13, 14, 15; 21 J/2, 3, 4, 5, 6, 7.
8.	DNRE July/88	General publication release notice.
9.	GSC August 9/88	Regional geochemistry and lake sediment water geochemical reconnaissance data (parts of 21 G and 21 H).
10.	DNRE Sept./88	General publication release notice.
11.	GSC Oct. 24/88	Till geochemistry over the northern part of the Miramichi Zone and vicinity (parts of 21 O/8, 16; 21 B/5; 21 P/12, 13).
12.	GSC Oct. 24/88	High resolution aeromagnetic total field and vertical gradiometer surveys. 21 O/1, 2, 7, 8, 10, and 21 P/4W.
13.	Nov. 8/88	Lithogeochemistry of selected rock samples, Riley Brook east (21 O/3E).

PUBLIC AWARENESS ACTIVITIES

During 1988, the Geoscientific Data Section was extensively involved in activities to increase the general public's awareness of New Brunswick's rich and diversified mineral resources.

Several discussion were held with the New Brunswick Mining Association on the topic of increasing the profile of New Brunswick's mineral industry. The Association would like to see more general information on our provincial mineral resources made available, and is willing to produce audio/visual programs and brochures highlighting its association members and the products produced by this group.

The continuance of activities that publicize the work being done under the Canada-New Brunswick MDA (1984-89) was another task carried out by this Section. A summary of these activities follows.

DISPLAYS:

Three new displays associated with public awareness activities were completed in 1988. The first display, produced by the Geological Surveys Branch, was exhibited at the Annual

General Meeting of the Prospectors and Developers Association in Toronto. It was part of the Provincial Geologists geoscience exhibit forum whose objectives are to publicize the various activities carried out by or for the participating provinces and territories. The same display was utilized at the Gold Symposium - New Brunswick 1988 that was held in Saint John, New Brunswick in June.

The second display was created for the Industrial Minerals Internation Congress that was held in Boston, Massachusetts in April, 1988. The theme of this display was New Brunswick's diversified industrial mineral base. Delegates at this congress were from all parts of the world and it is felt that they became well acquainted with our rich industrial mineral industry.

The industrial mineral display was also utilized at the CIM (Canadian Institute of Mining and Metallurgy) District 1 Meeting that was held in Fredericton in September. The theme of this meeting was Atlantic Canada's Mines: Consumers and Producers.

The third display, aimed at the general public, in particular high school students, publicizes the various technical and professional jobs that are available within New Brunswick's mineral resource sector. This display and a brochure were produced for Energy, Mines and Resources Canada, Communications Branch, under the MDA. These, along with the Province's potash display, were exhibited at the CIM District 1 Meeting.

EDUCATION PROJECT:

In 1988, Energy, Mines and Resources Canada, Communications Branch, received a proposal from G. Martin of Language Unlimited to extensively research, compile, and produce a manuscript to increase public knowledge about our Province's rich mineral heritage.

This proposal was accepted by EMR based on the success of Ms. Martin's junior high school MDA pilot project, called "On The Rocks".

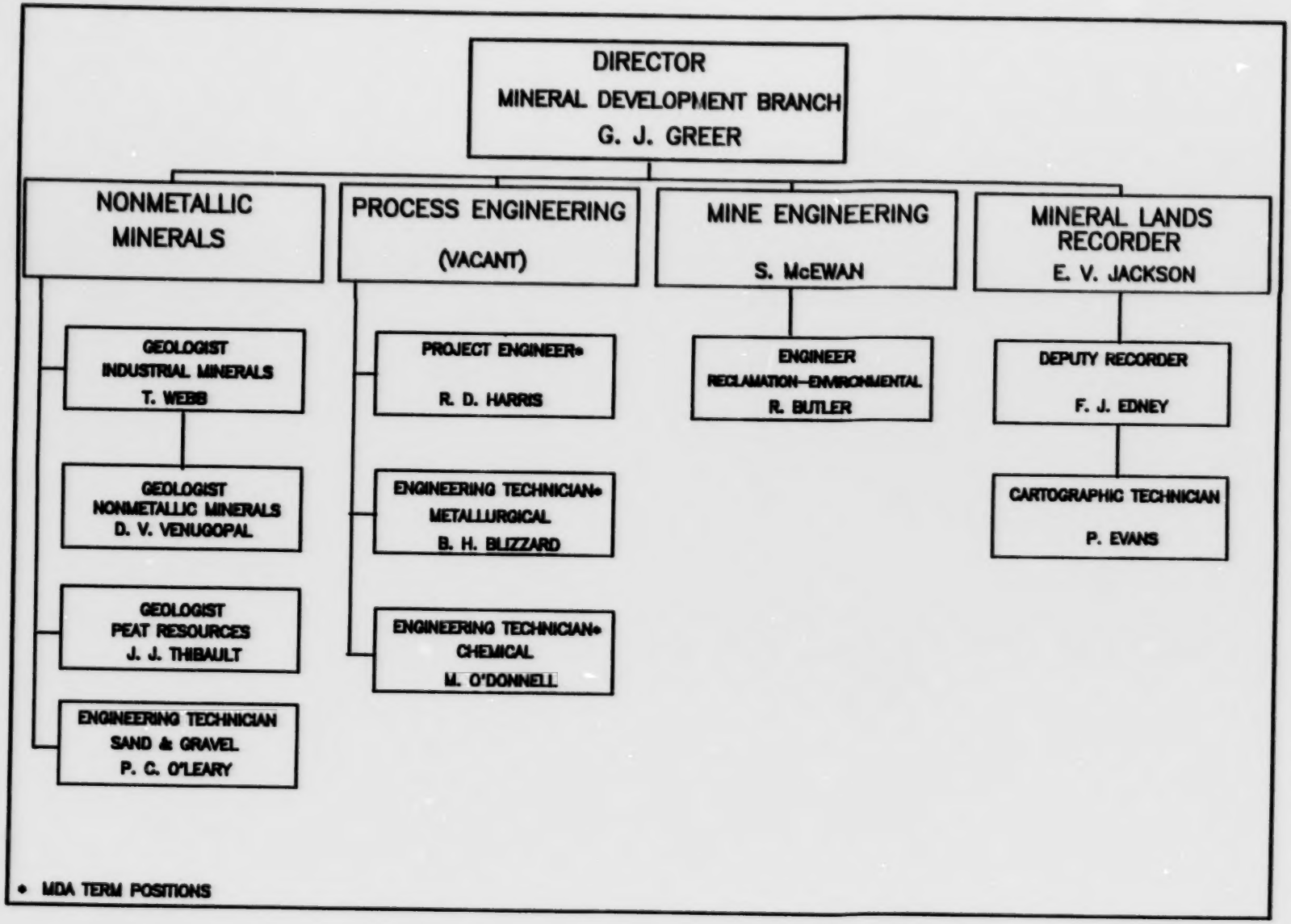
AUDIO/VISUAL PRODUCTIONS:

One of the highlights of the 1987 year was the completion of the first of four Atlantic Geoscience Society's video productions. The video, called "The Mineral Wealth of Atlantic Canada" was extremely well received by both industry and the education community within the Atlantic Provinces. In 1988, the second video, "The Appalachian Story", was completed.

Each year, the Geoscientific Data Section receives requests from school teachers for information on mineral resources and geoscience-related topics in audiovisual format or print. Gradually, the Section is building up a collection of videos, films, and slide programs for loan to various interest groups. Some of the titles that are available from the Geoscientific Data Section include:

1. "The Awakening Giant"
2. "Sensible Sequence"
3. "Coastline Conservation"
4. "The Beach - A River of Sand"
5. "Mineral Industries of New Brunswick"
6. "New Brunswick's Peat Resources"
7. "Carboniferous Drilling Project"
8. "Taming a Hazardous Waste with Lime"
9. "Lime - The Versatile Chemical"
10. "The Mineral Wealth of Atlantic Canada"
11. "Peat Research Centre - Shippagan"
12. "The Appalachian Story"

MINERAL DEVELOPMENT BRANCH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PEAT AND COASTAL ZONE RESOURCES

Jacques J. Thibault, Geologist

PEAT

A project was funded and completed under the Canada-New Brunswick MDA in 1988: "Reclamation options for abandoned commercial peatlands - Open File Report 88-7". The objective of the study was to complete a comprehensive bibliographical research of the possible uses of commercial peat bogs after the sphagnum peat reserves are exhausted, and to identify options for applied research projects.

Aerial photography of the peat-producing areas in New Brunswick was obtained between May 29 and June 4, 1988. For each producing bog, two maps are being prepared: 1) land usage, and 2) drainage network. These maps will be released at a later date.

The provincial peatland data base was adapted to dBASE III+ format and can now be used directly on microcomputer systems. This project was carried out in cooperation with the Information Systems Branch.

COASTAL ZONE

The first of a series of coastal zone videos of the New Brunswick coastline was released by the Geological Survey of Canada as Open File 1740: "The Coast of New Brunswick from Richibucto Cape to Point Escuminac, by J. Thibault and D. Frobel (59 min.)".

A beach nourishment plan for Parlee Beach Provincial Park, Shediac, has been initiated in cooperation with the Tourism, Recreation and Heritage Department.

A poster entitled: "Coastal Zone Studies in New Brunswick" was presented at the Annual Meeting of the Geological Society of America, in Portland, Maine, U.S.A. The display was part of a Symposium on "Coastal zone management strategies in the northeast: regional response to changing sea level and shorelines."

MINE ENGINEERING

S. McEwan, Mining Engineer

The Mineral Development Branch of the N.B. Department of Natural Resources and Energy has two specific objectives in managing New Brunswick's mineral resource. These objectives are the proper exploitation of the mineral resource and protection of individual rights before, during, and after this development. Attainment of both of these objectives involves the administration of the Mining Act in a manner that ensures protection of both the resource and the individual. The Mine Engineering Sector of the Branch is immediately involved in fulfilling both of these obligations.

In order to achieve these objectives, Mine Engineering is concerned with the following aspects of the N.B. Mining Act:

1. - the analysis and assessment of any new mining projects proposed within the Province. This is achieved through the evaluation of feasibility reports, reclamation, and waste management plans, as they pertain to the guidelines outlined in the Mining Act. These reviews involve participation by other departments (i.e. Crown Lands, Agriculture, and Municipal Affairs & Environment) that may be affected by establishment of a new mineral development.

2. - the monitoring of existing mining operations through the review of mine plans, site inspections, and statistical analysis of production, labour, and capital expenditures. This is an ongoing process to guarantee that the Provincial Government is kept fully aware of the state of well-being of the mining industry in the Province.

3. - the promotion of mining in the Province through support in the application of Mineral Development Agreements and other forms of monetary or technical assistance. These programs, once implemented, are monitored by the Mine Engineering Sector to ensure that the finances are being properly directed and objectives achieved, within the allocated time frame.

4. - maintaining an awareness of any other factors, be they economic, labour, or market oriented, which may affect the N.B. mining industry.

MINING DEVELOPMENT

The following is a brief summary of new mining activity in the Province for the previous year:

During the early part of 1987, Caribou New Brunswick Mining Ltd. made application for a mining lease on the property pre-

viously owned by Anaconda Canada Ltd. Their proposal is for a 2000 ton/day cut-and-fill mine producing a bulk zinc/lead concentrate. The operation will eventually employ approximately 180 people and expend $40 000 000 of investment capital.

Development of the property began in the latter part of 1987 with work progressing well into the early part of 1988, when it became apparent that required equity financing for the project would not be forthcoming through the normal means. A concerted effort was begun by both the Provincial Government and company representatives to find other sources of financing for this portion of the project. A suitable investor was found and the required monies put into place after the Province of New Brunswick agreed to supply a loan guarantee in the event that Caribou could not repay the investment. This action then opened the way for Caribou to acquire suitable debt financing for the remainder of the development.

At this time, Caribou has completed the building of a "starter dam" for the tailings pond, carried out extensive underground drilling for mine layout, and almost completed the expansion of the existing mill. A public meeting was held in December, 1987 concerning the environmental aspects of the proposed operation; the reclamation plan is in the final stages of approval. The delay in acquiring the necessary financing has delayed the start-up date by approximately four months and is presently November 1988.

A similar situation arose at the Murray Brook property where Northumberland Mines Ltd. had proposed a 1000 ton/day gold-silver, vat-leaching operation. This gossan-type open-pit deposit will employ approximately 30 people for a minimum of six years. In the latter part of 1987, an attempt was made to acquire equity financing. However, following the October 19 stock-market incident, investor confidence was low and the required financing could not be attained. This lead to a merger of Northumberland Mines with a Nova Scotia company, NovaGold Resources Inc. NovaGold has a proven record for being able to raise capital for mining projects, and has received federal loan guarantees through the Atlantic Canada Opportunities Agency. The company is presently attempting to raise equity financing through a $2 million offering of limited partnership units.

The project includes an approved reclamation program, and a revised feasibility plan has been submitted as part of the application for a mining lease. Some work is underway to upgrade roads into the site and construction should commence in the latter part of 1988, once financing is complete.

Heath Steele Mines proceeded with the Stratmat exploratory decline and took bulk samples for metallurgical testing; initial results look promising and a decision is expected in

early 1989. If approved, the mine/mill will operate at a rate of 2000 ton/day and employ approximately 200 people. Capital expenditure would be in the range of five million dollars.

Gordex Minerals implemented a new earthen vat-leaching system that has eliminated a number of operating problems, enabling them to continue leaching throughout the winter.

MINERAL DEVELOPMENT AGREEMENT (MDA)

Three MDA projects are presently underway that involve the Mine Engineering Sector. The projects are subject to review by the Mineral Development Branch to ensure that monies are being spent properly, schedules are being maintained, and objectives met. The following is a brief description of each of these projects.

1. Rock Mechanics Program for Cut-and-Fill Mining

This project was initiated in 1987 in conjunction with the Potash Company of America in Sussex, N.B. The objectives of this project are as follows:

(a) ensure overall stability of the mine

(b) minimize and understand local ground control problems in stopes and entryways

(c) maximize safety - both to people and resource

(d) improve measurement and analytical techniques

(e) optimize extraction of the ore and increase productivity and efficiency

(f) transfer ideas and technology to Canadian mining industry

The project has proceeded well with underground monitoring stations placed in stopes and main entryways. Information has been gathered from these locations and compared to the numerical computer model that has been established for the mine. Once the model is properly adjusted, most mining sequences could be simulated on the computer for rock mechanics purposes.

2. Use of Backfill in N.B. Potash Mines

This project was initiated by Denison-Potacan Potash Company in Sussex, N.B. to assist them in returning their salt tailings underground in a manner that would enable them to extend existing mineable reserves. In addition to extending the life of the operation, it would improve the capability of predicting ground behaviour, thus increasing safety and potash productivity.

Phase I of this project has been successfully completed with the determinatin of engineering properties of waste-salt backfill and host rock, and the effect of backfill on convergence and creep of mine openings by mathematical and numerical modelling.

Phase II is presently underway with the main objective being to confirm the laboratory and engineering analysis of Phase I in the field. It is intended that this will prove the support capability of backfill and define the placement means/ consolidation process/and time-dependent events that will enable second stage mining to proceed in a timely and efficient manner, at the same time ensuring both the safety of the resource and the people working there.

3. Heath Steele Waste-Rock Study

Heath Steele Mines has a significant quantity of acid-generating waste rock on its property. The purpose of this project is to develop and evaluate practical reclamation measures for control of this problem. The program will be carried out in three phases over a two-year period.

Phase I activities will review the topography of the property and the characteristics of the waste-rock piles in order to determine the potential environmental benefits from the project.

Phase II will establish baseline conditions for the waste-rock piles and will include a mineralogical assessment, identification of acid-producing bacteria and their acid-producing potential.

Phase III will consist of column tests to determine the characteristics of potential covers for the waste-rock piles.

The total expected cost of this project will be $317 000.

MINE RECLAMATION

R. Butler, Mine Reclamation Engineer

Through the New Brunswick Mining Act and its regulation, all developing mining operations are required to implement a program for the protection, reclamation, and rehabilitation of the environment.

The reclamation plan is considered part of the Mine Feasibility Study and is developed during the initial design phase of a mining project.

If the reclamation plan is properly engineered it may prevent major environmental impacts from occurring and will result in a mine site that is more readily rehabilitated and at a much lower cost to the mining company.

In the administration of the Mining Act, mine reclamation engineering involves:

1) Inspection of existing mining operations in the Province; review of their reclamation practices; and technical support for reclamation programs.

2) The analysis and review of new mining projects in the Province; review of feasibility studies with emphasis on reclamation and rehabilitation; liaison between Natural Resources and Energy, Agriculture, and Municipal Affairs and Environment for assistance in the review of the reclamation program.

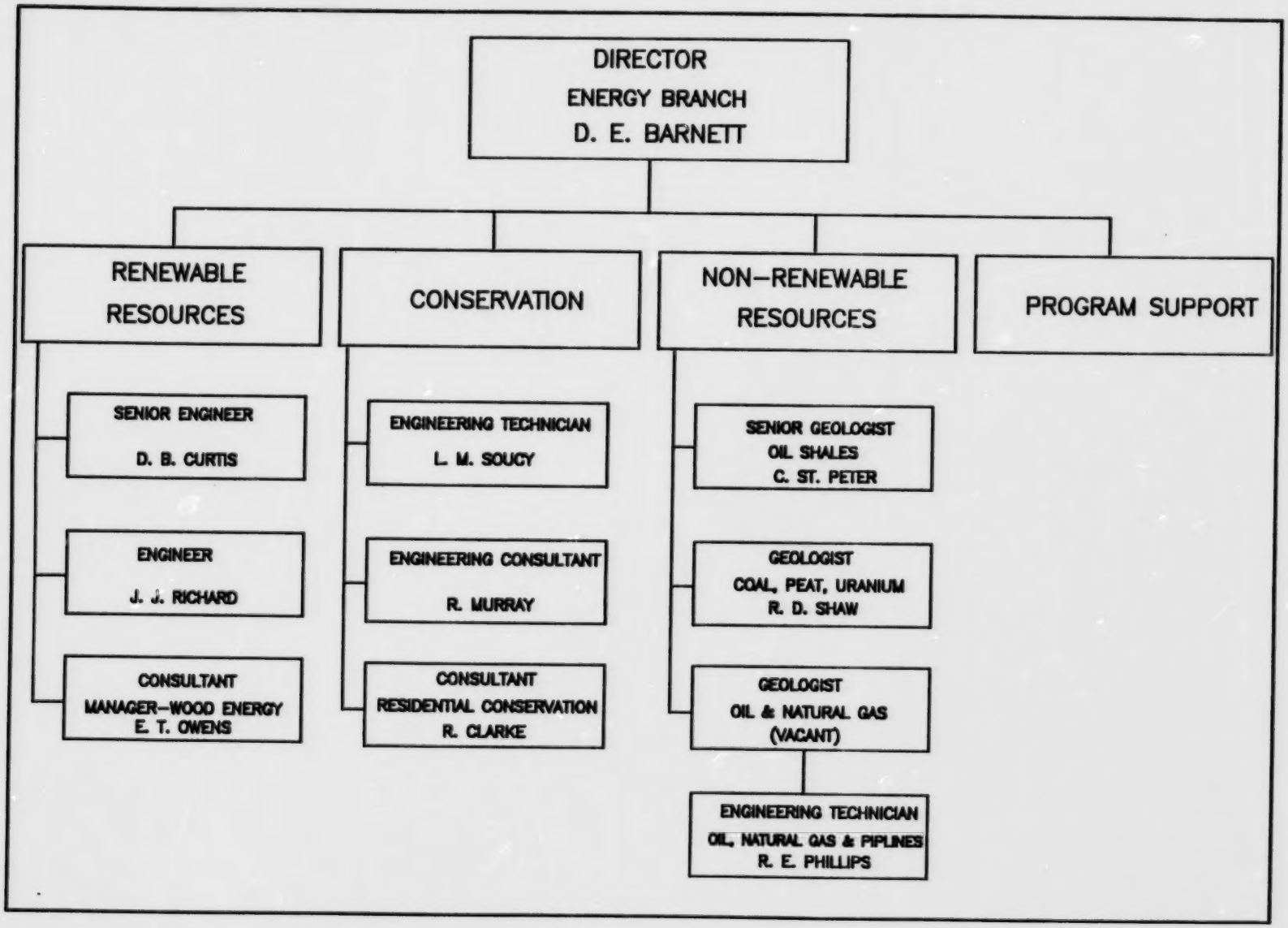
This year, there have been five applications for reclamation plan approvals, which are under review at this time.

Reclamation engineering also involves the research into lessening the environmental impacts of existing or closed mining operations. The main issues apparent at abandoned mine sites include: reactive acid tailings, acid mine drainage, and general land rehabilitation.

The Province provides financial assistance and offers technical support for various reclamation and rehabilitation programs. An example of this is the support given to Brunswick Mining and Smelting and their Heath Steele Waste-Rock Study. This is a project designed to investigate the capping of a waste-rock pile to lower or prevent acid generation.

The Department of Natural Resources and Energy has representation in the technical working group of the MEND (Mine Environment Neutral Drainage) program (formerly Reactive Acid Tailings Study RATS).

ENERGY BRANCH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ACTIVITIES OF THE ENERGY BRANCH

Clint St. Peter, Energy Geologist

The nonrenewable resources section of the Energy Branch is responsible for the administration, management, investigation, and development of coal, oil, natural gas, oil shale, geothermal energy, and uranium. The Branch is responsible for the administration of the Oil and Natural Gas Act, the Bituminous Shale Act, the Pipeline Act, the Underground Storage Act, and the Coal Policy, and to ensure adherence to the various licences, permits, and leases thereunder.

CANADA-NEW BRUNSWICK MDA PROJECTS

The following projects have been completed:

1. The diagenetic history of the oil- and gas-bearing Albert Formation sandstones.
2. Sedimentary facies and sandstone geometry within the Stoney Creek oil and gas reservoir.
3. Bench-scale physical beneficiation of Albert Formation oil shale.
4. The potential for enhanced oil recovery by steam injection into the Irving/Chevron East Stoney Creek No. 1 well.
5. The potential of New Brunswick shale oil as an asphalt feedstock.
6. An assessment of the calcium and magnesium content of oil shale at Albert Mines, New Brunswick. This project was funded under the Mineral Investment Stimulation Program (MISP) and by Canadian Occidental Petroleum.

The following projects have been initiated under the MDA:

1. The physical and chemical characterization of oil shale and coal ash from N.B. Power circulating fluidized bed (CFB) combustor in Chatham.
2. The feasibility of coupling an oil shale retort with CFB Chatham. This project is being co-funded by Canadian Occidental Petroleum.

PROVINCIAL PROJECTS

In April 1988, the Branch successfully hosted the Northeast International Committee on Energy (NICE) conference in Saint John, N.B. This is the annual energy conference of the New England Governors and Eastern Canadian Premiers.

The Branch developed, in 1988, a policy in relation to gasoline pricing in New Brunswick. Efforts are continuing via the Energy Supply Allocation Board to produce a contingency plan for oil storage in New Brunswick. In this regard, approval of intent has been given to draft regulations under the Underground Storage Act.

Participation on the Interprovincial Committee on Coal continued during 1988.

A poster display on the facies and environments of deposition of the Upper Devonian to Lower Carboniferous Horton Group was given at the annual meeting of the Geological Association of Canada in St. John's, Newfoundland and at the CIM - District 1 Meeting in Fredericton, N.B.

PROVENANCE AND TECTONIC RELATIONSHIP OF THE STONEY CREEK OIL AND GAS FIELD - MDA

S.L. Foley and J.P.A. Noble
Department of Geology, University of New Brunswick

The Stoney Creek Oil and Gas Field is a producing field located 16 km south of Moncton, New Brunswick. The hydrocarbons are reservoired in sandstones of the Lower Carboniferous Albert Formation. The Albert Formation is a lacustrine and associated fluvial-deltaic sequence deposited in an elongated northeast-trending basin known regionally as the Moncton Subbasin (Pickerill and Carter 1980). The Albert Formation is the middle grey formation of the Horton Group and is overlain by red beds of the Moncton Formation (Horton Group) and underlain by red beds of the Memramcook Formation (Horton Group). In the vicinity of Stoney Creek, the Horton is overlain unconformably by the Enragé Formation. The oil and gas field is located along the south flank of the Westmorland Uplift (Figure 25) that bifurcates the Moncton Subbasin in the east. Limited exposure of the uplift indicates a coarse crystalline, porphyritic granite terrain (Pickerill et al. 1985).

Well cuttings and lithologic logs were used to interpret sandbody geometry within the field. The Albert Formation onlaps to the north onto the Westmorland Uplift and dips and thickens off the high. Intercalated sandstones within marginal lacustrine shales also onlap yet thicken off the uplift. This indicates that the uplift directly north of Stoney Creek acted as a passive high and contributed limited detritus to the area (Foley and Noble 1988). Sediments appear to have been transported from east of the field and were deposited at Stoney Creek as fluvial/deltaic or marginal lacustrine facies.

The southeast segment of the Moncton Subbasin (Hillsborough Subbasin) appears, from similar structural and stratigraphic characteristics, to be genetically related to the Sackville Subbasin to the southeast, as described by Martel (1987). These two basins possibly developed in an en echelon geometry in response to strike-slip tectonics. The Westmorland Block to the north of the Sackville Subbasin supplied the greatest concentration of detritus to that basin. Although it is difficult to delineate the basement structure east of Stoney Creek it is highly suspect that the Westmorland Block in that area was also a major contributor of sediment to the Moncton Subbasin. This is supported by paleocurrent trends recorded from exposures east of the Petitcodiac River which all indicate dominant south and southwest transport directions of the sands, implying the existence of a source area to the northeast (Foley and Noble 1988).

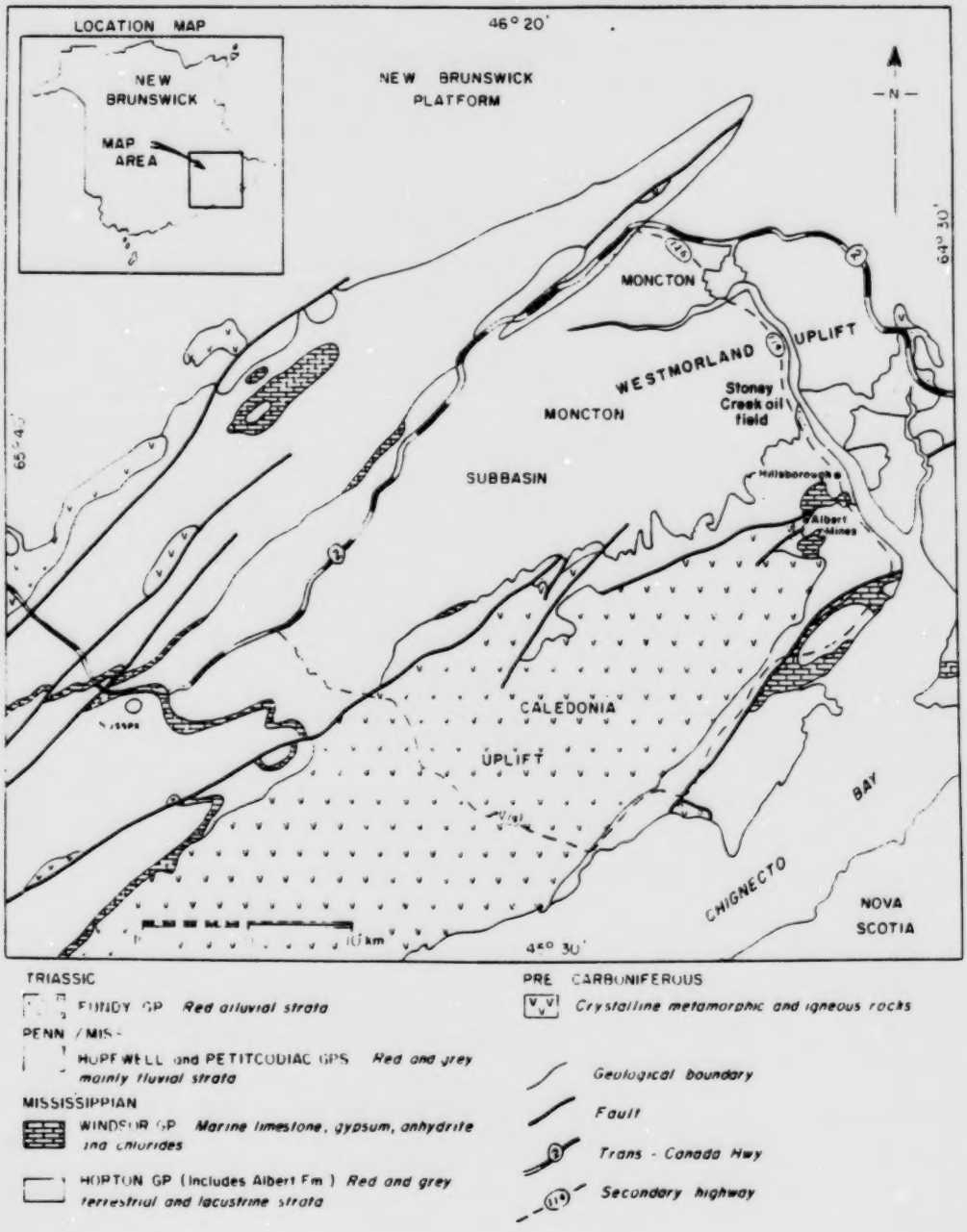

Figure 25. Generalized geology of the Moncton Subbasin (after St. Peter 1987).

The Albert Formation sandstones at Stoney Creek are generally arkosic lacking any substantial contribution from a volcanic source. This casts doubt on the likelihood that the Caledonia Uplift (a greenstone terrain to the south; Pickerill and Carter 1980) was a major source contributor to the Stoney Creek area. Assuming the Westmorland Uplift was a positive feature, sediments would have been shed off that high to the south and west, into the axis of the basin (Foley and Noble 1988). Stoney Creek represents a play onlapping along a passive segment of the Westmorland Uplift.

Hydrocarbon traps have been controlled by both structural and stratigraphic features. The dominant structural feature within the field is an east-west-trending fault which cuts the southern end of the field. The southern block has dropped relative to the northern block. Movement along the fault was initiated in Albert time and was terminated prior to deposition of the Enragé Formation, therefore was not offset by the Enragé unconformity. A thicker section of Moncton Formation was preserved on the hanging wall and included the Boyd Creek Tuff. The Hillsborough Member (Moncton Formation) was poorly preserved within the main field. Over most of the oil field, the Hillsborough Member has been eroded by the Enragé unconformity. However, the member is preserved along the western margin. It lies with angular discordance on the Weldon Member (Moncton Formation) in the northwest and becomes disconformable in the southwest. The Hillsborough Member consists of interbedded conglomerates and red mudstones. Composition of the coarse fraction indicates an intrusive granitoid provenance; probably the Westmorland complex. Other faults crosscut the field all with a component of normal movement but strata within the field, although fractured, are relatively undisturbed.

In conclusion, the available data strongly suggest that the dominant source of the Albert sandstones in the vicinity of Stoney Creek was the Westmorland Block to the east.

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HORTON GROUP FACIES IN THE MONCTON SUBBASIN

Clint St. Peter, Energy Geologist

The Moncton Subbasin (Figure 26) of southeastern New Brunswick is a relatively small northeast-trending, wedge-shaped depocentre in the larger Maritimes Basin. The oldest strata in the Moncton Subbasin comprise the Upper Devonian to Lower Carboniferous Horton Group. The Horton lies on a basement of intrusive rocks and deformed sedimentary, volcanic, and metamorphic rocks.

Traditionally, the Horton Group has been divided into the basal red beds of the Memramcook Formation, the medial grey beds of the Albert Formation and the upper red beds of the Moncton Formation (Gussow 1953; Carter and Pickerill 1985). Locally, the Horton contains strata assigned to an unnamed formation of uncertain stratigraphic position.

The facies of the Horton Group and their environmental interpretation may be summarized accordingly:

FACIES	ENVIRONMENT
Angular clast polymictic conglomerates, lithic wacke; minor mudcracked mudstone and caliche limestone	Alluvial fan - braided stream complex
Angular clast polymictic conglomerate, lithic and feldspathic sandstone with interbeds of siliciclastic clast limestone, kerogenous mudstone and shale (Albert Formation only)	Alluvial fan - marginal lacustrine
Cross-bedded and laminated sandstone and conglomerate; minor nodular limestone and kerogenous mudstone (Albert Formation only)	Fluvial-deltaic and marginal lacustrine
Mudstone with mudcracks and rain prints and limestone and gypsum nodules; minor sandstone and nodular limestone and (in Albert Formation only) kerogenous mudstone	Fluvial interchannel and distal alluvial fan and (in Albert Formation only) lacustrine mudflat
Dolomitic kerogenous shale, dolomitic and calcareous kerogenous mudstone; minor sandstone and limestone (Albert Formation only)	Perennial lacustrine and lacustrine mudflat

FACIES	ENVIRONMENT
Nodular limestone, carbonaceous algal limestone; minor dark grey mudstone and algal coal (Moncton Formation only)	Algal swamp
Halite, muddy halite, shale; minor anhydrite and glauberite (Albert Formation only)	Playa lake

Surface exposures and borehole data indicate that coarse alluvial-fan and braided-stream deposits are dominant near basement uplifts and basement-bounding faults. Lacustrine strata are associated with these coarse deposits. Clast compositions and paleocurrent trends approximately at right angles to the basin margin demonstrate a local source of detritus.

The axial part of the subbasin is characterized by fluvial facies, fine-grained alluvial beds, and local playa-lake evaporites. Fluvial sands are moderately mature and paleocurrent directions are either northeast or southwest along the long axis of the subbasin.

The inception of the Maritimes Basin has been ascribed to rifting (Howie and Barss 1975; McCutcheon and Robinson 1987) or to a strike-slip, pull-apart origin (Bradley 1982). The oblique orientation of fold axes to fault traces, the known reverse movement on some faults, and the demonstrated right-lateral offset on faults and map units imply a dextral transpressive evolution for the Moncton Subbasin. In this regard, the basement uplift along the Indian Mountain Fault (Figure 26) may be a positive flower structure and not a rift-related horst. Lithic detritus in Horton conglomerate and sandstones is undoubtedly from adjacent basement rocks suggesting that offsets on strike-slip faults were modest.

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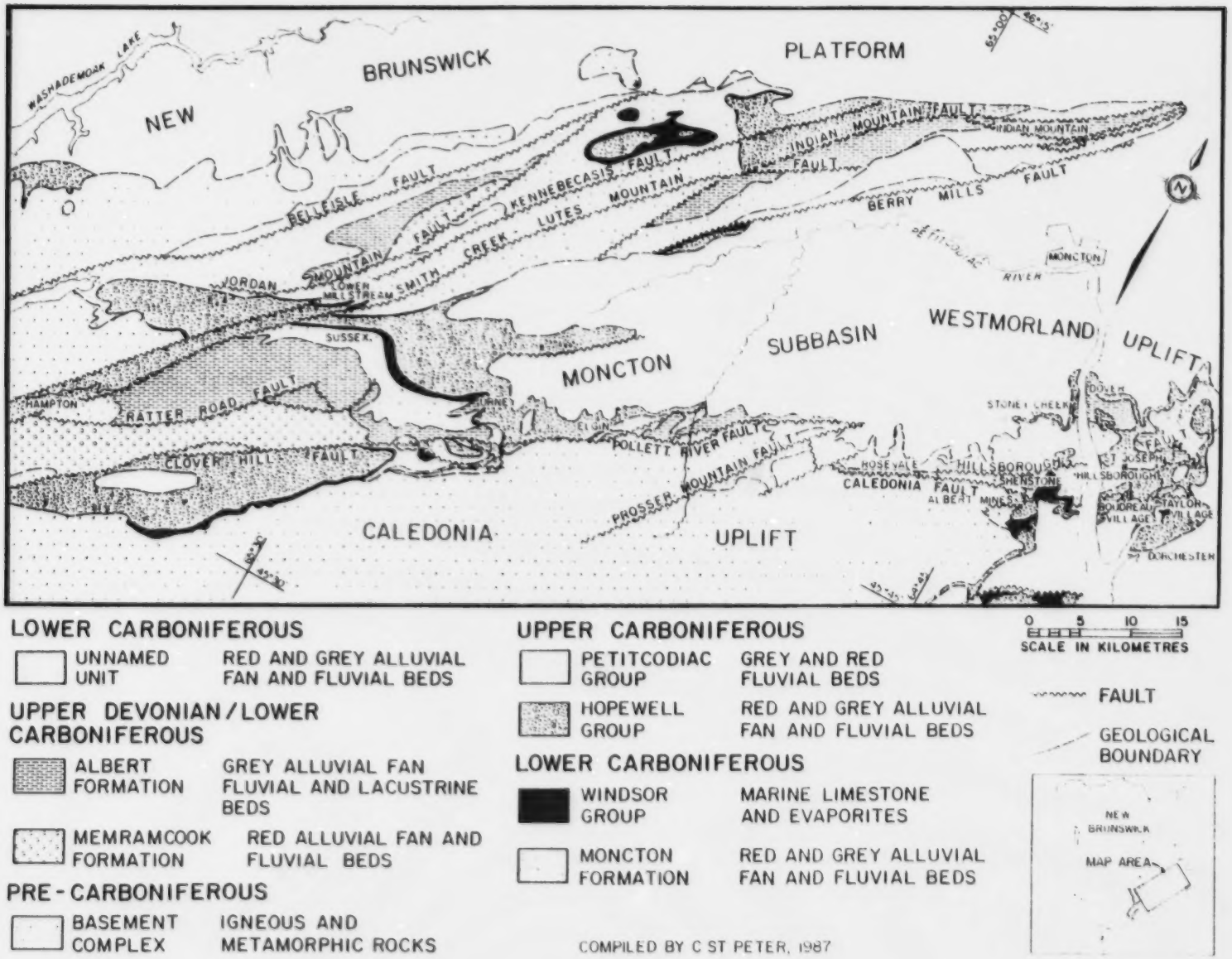

FIGURE 26. Regional geology of Moncton Subbasin.

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SECTION II

GEOLOGICAL SURVEY OF CANADA

FIELD RELATIONS, PETROLOGY, AND ECONOMIC POTENTIAL OF VOLCANIC AND PLUTONIC ROCKS, EASTERN CALEDONIAN HIGHLANDS, SOUTHERN NEW BRUNSWICK*

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An ongoing mapping project, begun in 1985, is defining the field relations and map units in the Caledonian Highlands east of Saint John in southern New Brunswick (Figure 27). Rocks in this area consist mainly of low-grade metavolcanic, metasedimentary, and plutonic rocks and are generally considered to be typical of the Avalon Terrane of the northern Appalachian Orogen (e.g., Ruitenberg et al. 1979; Nance 1986). Progress reports for this project were previously presented (Barr 1987; Barr and White 1988), and results of the mapping from 1985 through 1987 have been published as an Open File Report (Barr 1988). During the summer of 1988, mapping was extended to the south and west, to complete the map area indicated on Figure 27, and integrate with the work of McLeod (1987). Future mapping, planned for 1989, will extend to the Saint John area to integrate with studies by K.L. Currie (e.g., Currie 1987).

In addition to the mapping, this study includes the first thorough documentation of the petrochemistry of the volcanic and plutonic rocks in the map area, as well as radiometric dating, and hence will provide a significant data base for regional correlations, tectonic interpretations, and exploration programs. Metavolcanic and metasedimentary map units include mafic tuffaceous phyllite and schist, arkosic metasedimentary rocks, subaerial rhyolite and basalt flows, intermediate to felsic crystal tuffs, laminated siltstone, felsic lapilli tuff, and epiclastic conglomerate. Chemical characteristics of the mafic units suggest that they were formed in a rifting environment within a volcanic arc.

The stratified rock units have been intruded by varied plutonic rocks, including an older (600 to 625 Ma) group consisting of the Goose Creek leucotonalite, Alma pluton (diorite and quartz diorite), Forty Five River pluton (granodiorite to granite), and Point Wolfe River pluton (diorite to granite), and a younger (about 550 Ma) suite including the Bonnell Brook pluton (diorite and syenogranite) and Mechanic Settlement pluton

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*Contribution to the Canada-New Brunswick Mineral Development Agreement, 1984-89. Project carried by the Geological Survey of Canada.

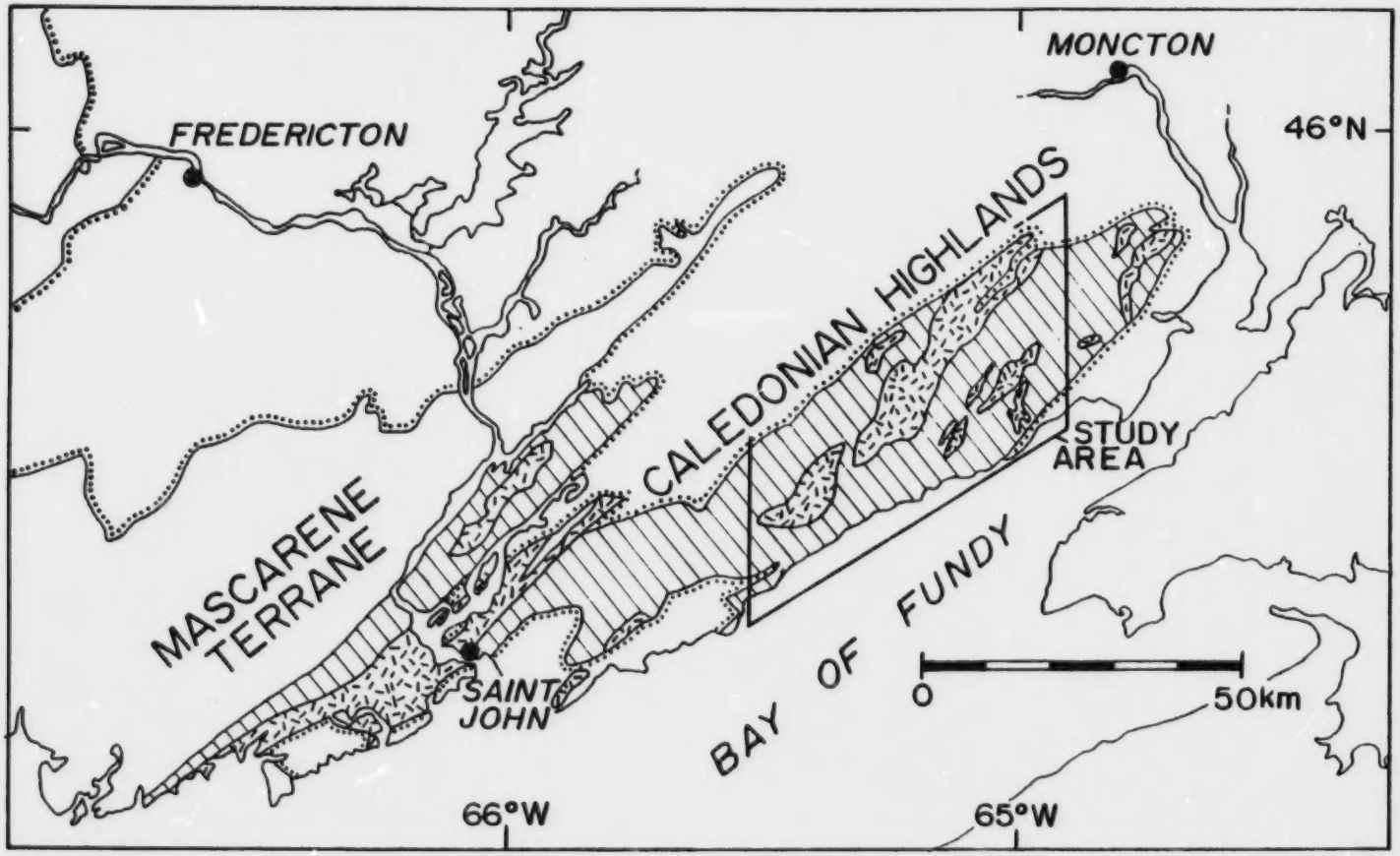

FIGURE 27. Location of the study area in the Caledonian Highlands (striped pattern) of southern New Brunswick. Random dash pattern indicates granitoid rocks.

(layered gabbro to diorite). Petrological characteristics indicate that the older group may be a comagmatic I-type suite formed in a subduction-related environment. However, the younger group has contrasting "bimodal" character, with the syenogranite being a highly evolved I-type granite and probably not comagmatic with the diorites and gabbros of apparently similar age. The syenogranite may be comagmatic with adjacent rhyolitic units, which may form one or more caldera complexes.

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U-Pb GEOCHRONOLOGIC STUDIES OF IGNEOUS ROCKS IN N.B.*

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This contribution summarizes the results of a U-Pb geochronologic and Pb isotopic study of igneous rocks in New Brunswick, including the work reported by Whalen and Bevier (1986, 1987). The purposes of this research are: a) to obtain precise crystallization ages for a variety of igneous and meta-igneous rocks in the province; b) to determine Pb isotopic ratios from the same samples; and c) to use these data to constrain petrologic, tectonic, and metallogenic studies.

Fourteen new ages along with six previously cited ages (Whalen and Bevier 1987; Bevier 1988a; Fyffe et al., in press) are listed in Table 5. Complete analytical results and detailed interpretations will be published elsewhere. During the summer of 1988, an additional 16 samples were collected for U-Pb dating (Table 6). The ages, Pb isotopic data, and their significance are briefly discussed below, and all sample localities are plotted in Figure 28.

MIRAMICHI TERRANE

A detailed map and description of Ordovician granites in the Miramichi terrane is found in Whalen (this volume). These deformed granites give Middle to Late Ordovician ages ranging from 448-470 Ma (Table 5), and the U-Pb zircon systematics reflect the presence of xenocrystic zircon and post-crystallization Pb loss (Bevier 1988a; Fyffe et al., in press). Although most of the ages are discordant, as evidenced by their high errors, the ages do constrain the timing of the earliest plutonism in the Miramichi terrane to Ordovician and not Precambrian as previously proposed (Rast et al. 1976; Fyffe and Pronk 1985).

The presence of xenocrystic zircon in these granites is compatible with their derivation from older continental crust at depth. Calculated upper intercepts with concordia range from 1.2-2.7 Ga. No geologic significance is attached to specific upper intercept ages because in some, if not all, cases they represent an average age for xenocrystic zircons of a variety of ages. For example, xenocrysts in the Meridian Brook granite, analysed by ion microprobe, give U-Pb ages of ca. 600-1800 Ma (Roddick and Bevier 1988), suggesting a heterogeneous source.

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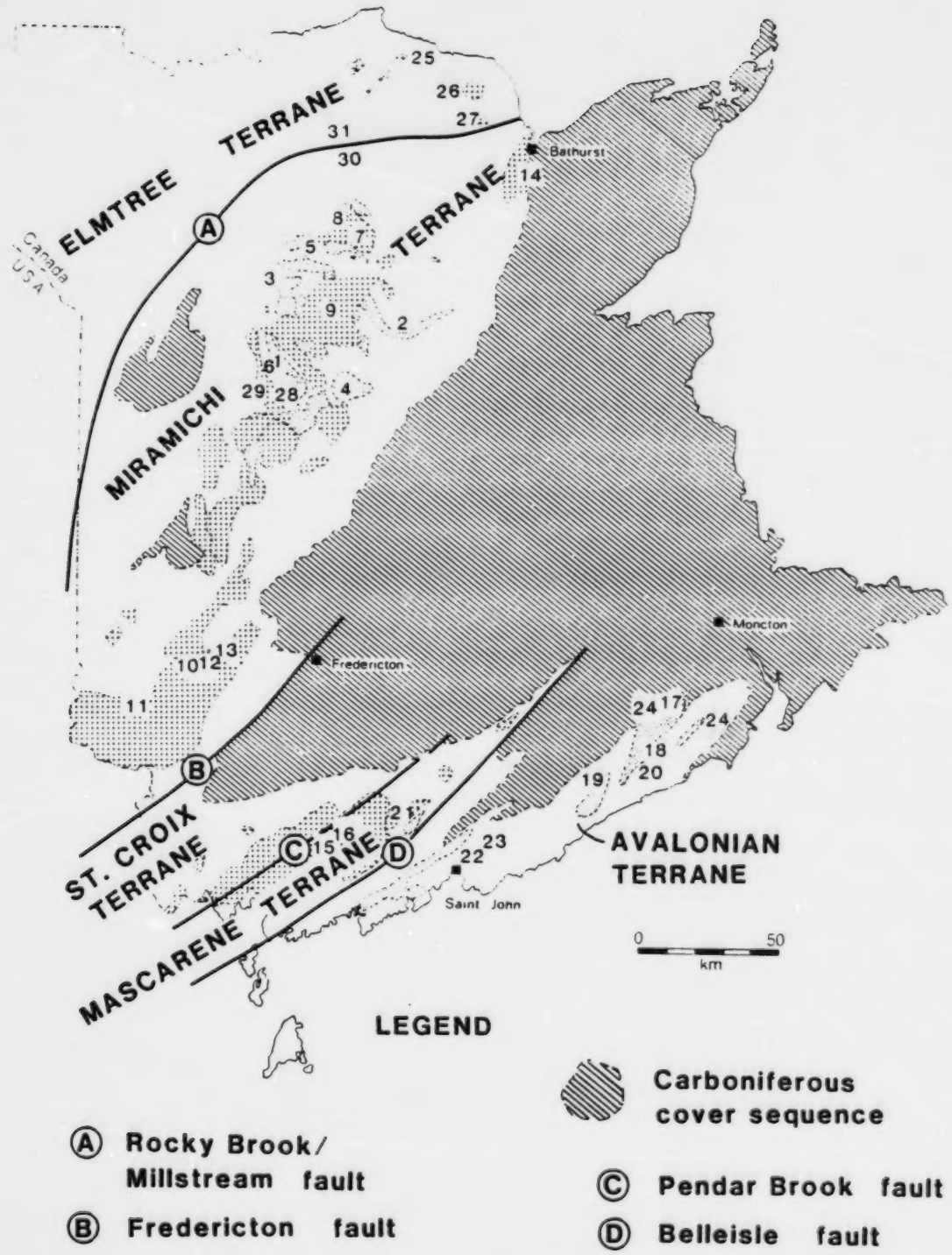

FIGURE 28. Map of plutons in New Brunswick, with sample numbers keyed to Tables 5 and 6. Terrane boundaries after Fyffe and Fricker (1987).

TABLE 5

U-Pb ZIRCON AGES

NAME	U-Pb AGE (Ma)
Miramichi terrane	
1. Fox Ridge augen granite	452 +15/-1
2. Mullin Stream Lake granite	458 +16/-1
3. Serpentine River granite gneiss	455 +12/-9
4. South Renous granite gneiss	448 +17/-16
5. Meridian Brook granite	470 +/- 1
6. Trousers Lake orthogneiss	434 +29/-6
7. Mount Elizabeth biotite granite	418 +/- 1
8. Mount Elizabeth alkali granite	414 +11/-1
9. North Pole Stream granite	417 +/- 1
Pokiok Batholith	
10. Hartfield Tonalite	415 +/- 2
11. Skiff Lake Granite	409 +/- 2
12. Hawkshaw Granite	407 +3/-2
13. Allandale granite	402 +/- 1
14. Pabineau Falls Granite	394 +/- 1
St. Croix-Mascarene terrane	
Saint George Batholith	
15. Magaguadavic granite	395 +/- 2
16. Mount Douglas Granite (Disappointment Lake)	367 +/- 1
Avalonian terrane	
Point Wolfe River Pluton	
17. Pollett River granite	625 +/- 5
18. quartz porphyritic granodiorite	615 +/- 1
19. Bonnell Brook granite	550 +/- 1
20. Coldbrook Group (?) rhyolite	548 +/- 1

Analytical techniques described in Parrish *et al.* (1987). Quoted errors are two standard errors of the mean.

TABLE 6

1988 SAMPLE LIST

21. Welsford peralkaline granite
22. Brookville orthogneiss and paragneiss (n=3)
23. New Airport road quartz diorite (Golden Grove suite)
24. Coldbrook Group (?) rhyolite (n=3)
25. Benjamin River quartz monzonite
26. Antinouri Lake Granite
27. Nicholas Dénys tonalite
28. Lower Tetagouche Group(?) paragneiss (n=2)
29. Redstone Mountain granophyre
30. Mulligan Gulch porphyry
31. Upsalquitch River bridge porphyry

New geochronologic data from the Mount Elizabeth biotite granite, North Pole Stream Granite, and the Pokiok Batholith (Hartfield Tonalite, Skiff Lake Granite) confirm the previous suggestion (Whalen and Bevier 1987; Bevier and Whalen, in press) that most of the undeformed plutons in Miramichi terrane, previously thought to be Devonian (Fyffe et al. 1981), are actually Late Silurian.

The four main phases of the Pokiok Batholith span the age range of 415-402 Ma (Siluro-Devonian). Although xenocrystic zircon is found in the Pokiok Batholith and some of the other Silurian plutons in the Miramichi terrane, it is not as prevalent as in the Ordovician granites.

A U-Pb (single crystal) age of 394±1 Ma for the Pabineau Falls Granite supercedes the preliminary age of 392 +81/-7 Ma (Bevier, unpublished data). Common Pb isotopic studies indicate that the Pabineau Falls Granite was derived from basement source rocks like those beneath the Elmtree terrane rather than those beneath the Miramichi terrane. This suggests that the original boundary between the Miramichi and Elmtree terranes was not necessarily the Rocky Brook-Millstream fault. Van Staal and Langton (1988) have also proposed this, based on structural evidence.

Initial Pb isotopic ratios from Miramichi granites of all ages indicate an old, upper crustal Pb component in the source area for these plutonic bodies (Bevier 1987). This Precambrian component has a range of Pb isotopic compositions somewhat similar to the range displayed by Precambrian granitic units from the Avalonian terrane in southern New Brunswick, raising the possibility that Avalonian basement is much more extensive in the substrate than previously supposed. The existence of a pre-Ordovician upper crustal continental basement to the Miramichi terrane helps constrain viable tectonic models for

generation of the middle Palaeozoic igneous rocks to continental settings, i.e., a back-arc basin or intracontinental rift, as suggested by van Staal (1987).

In addition to the new samples from the Miramichi terrane listed in Table 6, U-Pb ages are in progress on the Burnthill Granite, Gibson Granodiorite, and Sweat Hill Granite.

ST. CROIX-MASCARENE TERRANES

Two granites from the Saint George Batholith have been dated. The Magaguadavic granite from the western lobe of the batholith is 395±2 Ma old; the youngest phase of the Mount Douglas Granite located near Disappointment Lake (McLeod et al., in press) in the eastern lobe of the batholith is 367±1 Ma old, indicating a minimum time span of 28 Ma for formation of the Saint George Batholith. These ages are consistent with $^{40}Ar/^{39}Ar$ ages from the same sample localities (McLeod et al., in press), although they are younger than all the Miramichi terrane granites except the Burnthill suite (MacLellan et al. 1986). Dating of other phases of the Saint George Batholith (Utopia and Welsford granites) is in progress.

The interpretation of initial Pb isotopic ratios from the St. Croix-Mascarene granites is somewhat enigmatic (Bevier 1988b). The values suggest a radiogenic, upper crustal source, with Pb isotopic compositions intermediate between Avalonian and the less radiogenic Elmtree terrane sources. This may indicate a mixing of mantle and upper crustal components.

AVALONIAN TERRANE

U-Pb ages of 625-615 Ma for the Point Wolfe River Pluton and 550±1 Ma for the Bonnell Brook granite confirm that at least two periods of plutonism are preserved in the Caledonian Highlands. A 548±1 Ma age on a Coldbrook Group (?) rhyolite south of the Point Wolfe River Pluton necessitates that the contact between the two is tectonic and not intrusive as previously thought (Barr and White 1988). Several more rhyolites from this area were collected in 1988 in order to determine whether there are any volcanic rocks in the area that are older than the Point Wolfe River Pluton or whether it is totally fault-bounded by younger rocks.

WORK IN PROGRESS

The samples collected in 1988 were chosen for several reasons. Some, such as the rhyolites from the Caledonian Highlands described above, are necessary to further constrain the tectonic history in specific areas. Two others will constrain the age of gold mineralization (Mulligan Gulch, Upsalquitch River Bridge) in northern New Brunswick. Other

projects include the ages of Elmtree terrane granites, the age of the Brookville Gneiss (the oldest(?) rock unit in New Brunswick), and the metamorphic ages of Miramichi terrane paragneisses. In addition, all the 1988 samples will be analysed for Pb isotopes as part of an ongoing study of basement source rocks for granites within New Brunswick.

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SEDIMENTOLOGY, DIAGENESIS, AND ORGANIC GEOCHEMISTRY OF THE ALBERT FORMATION, MONCTON SUBBASIN, NEW BRUNSWICK*

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The Early Carboniferous Albert Formation occurs in the fault-bounded Moncton Subbasin in southern New Brunswick. The formation is about 1700 m thick and is primarily composed of fine to medium sandstones, oil shales, shale, and conglomerate. The sediments were deposited in a fluvial lacustrine setting (Pickerill et al. 1985). They host a small oil and gas reservoir in the eastern part of the subbasin (Figure 29).

In the eastern part of the subbasin, the Albert comprises three distinct lacustrine shales. Each sand package contains multi-story fining upward fluvial-deltaic sequences. In the western part of the subbasin, alluvial fans, sand flats, and shallow lacustrine subenvironments predominate with relatively minor deltaic incursions. In the east, (e.g., Albert Mines, Saint-Joseph, and Dover) the deep lacustrine condition is characterized by Type I organic matter and high total organic carbon (TOC) content (up to 30%) indicating anoxic bottom conditions. In the west, Type III organic matter (mostly terrestrial) and low total organic carbon content are indicative of shallow oxic conditions. Isopachs of the total shale thickness generally show a decrease in thickness toward the west. Shale isopachs, organic carbon, and organic matter type distribution suggest a ponded lake model.

Sandstones are predominantly subarkosic to arkosic in composition and contain carbonate clasts, siltstones, and rare volcanic grains. Carbonate clasts are predominantly intrabasinal in nature and occur in different forms; as bioclasts (primarily ostracodes), ooids, oncolites, and aggregate grains. These clasts are derived from the partially uplifted areas within the subbasin. The presence of such subaerially exposed emergent surfaces (e.g., calcretes) have also been recognized in the subsurface from characteristic cement microfabrics and lithology. These carbonate clasts are possibly derived from exposed areas during low lake levels and possibly from fault-bounded uplifted blocks around the basin.

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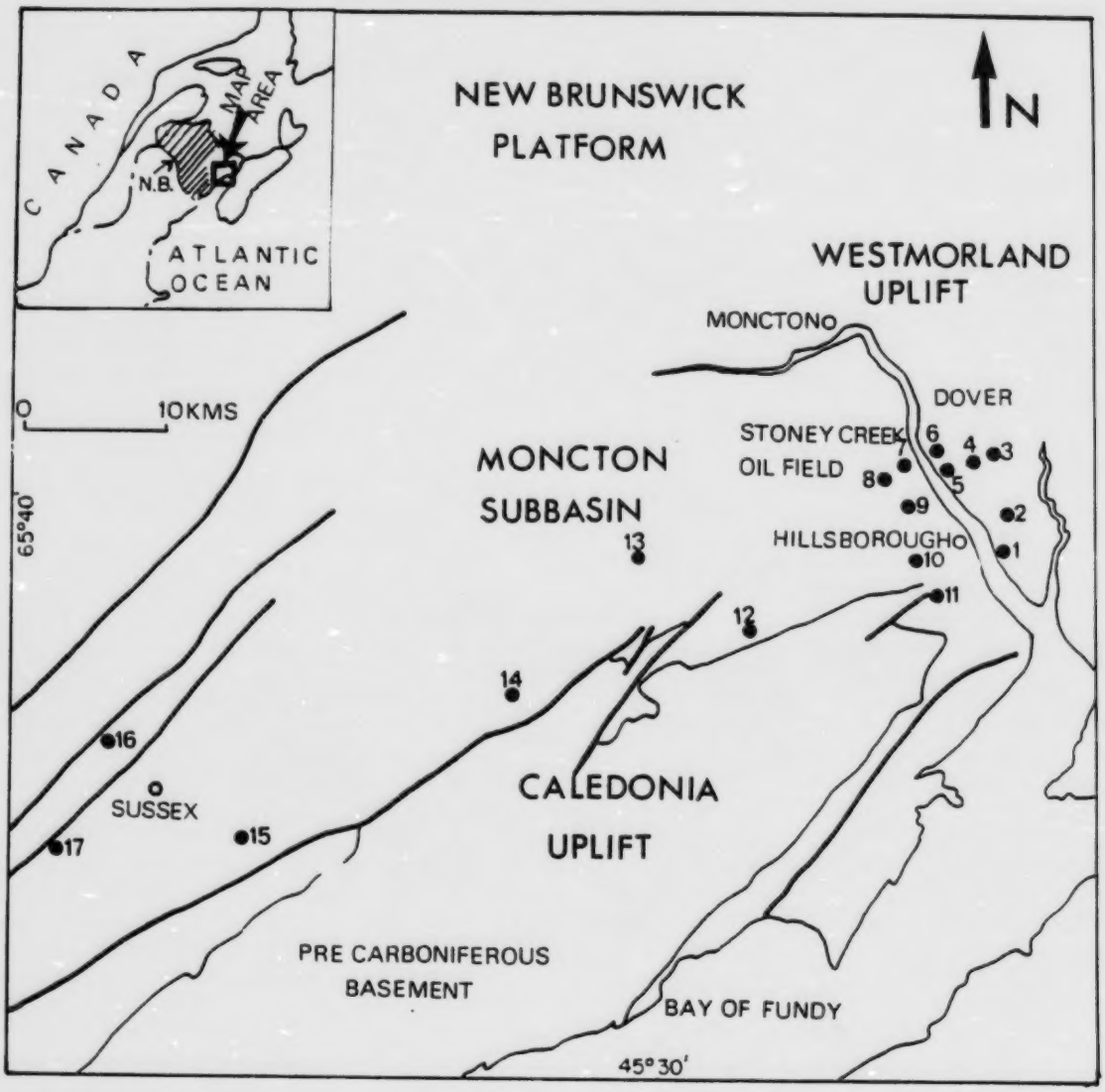
*Contribution to the Canada-New Brunswick Mineral Development Agreement, 1984-89. Project carried by the Geological Survey of Canada.



- borehole
1 Petro-Canada Boudreau-1
2 Arco Boudreau-1
3 Cartago Dover-1
4 Petro-Canada Dover-1
5 Arco Dover-1A
6 Petro-Canada Dover-2
7 Irving-Chevron E. Stoney Crk-1
8 Irving-Chevron Hillsborough-1

— fault
10 Can-Oxy Shenstone-1
11 Can-Oxy Albert Mines-9
12 Arco Rosevale-1
13 Irving-Chevron Little River-1
14 Irving-Chevron Lee Brook-1
15 United Pan Canadian McLeod Brook-1
16 Gulf Lower Millstream-1
17 Shell Apohaqui-1

FIGURE 29. Major tectonic elements of southeastern New Brunswick showing location of boreholes cutting the Albert Formation.

Most of the Albert Formation has undergone the mesodiagenetic stage of diagenesis with local levels of telodiagenesis. Diagenetic minerals include early diagenetic quartz overgrowth, chlorite, calcite, pyrite; and locally, kaolinite, smectite, and mixed layer clays (Chowdhury and Noble 1988). Multiple phases of quartz and chlorite cementation have been observed. Besides quartz and chlorite, late diagenetic events include formation of ankerite, development of solution porosity by dissolution of feldspars, carbonates, and clays, and generation of hydrocarbons. Ankerite cements occur in more deeply buried sandstones formed at about 100-120°C and show a variable distribution pattern in the subbasin. Shale analyses indicate up to 30% ankerite. It is suggested that the ankerite in the sandstones is derived by mass transfer of Fe and Mg from the interbedded shales.

Diagenetic mineral assemblages of the Albert Formation indicate a dominantly highly alkaline pore-water chemistry. However, an acid pore-water environment has been developed by expulsion of organic acids and CO_2 during thermal maturation of the organic matter prior to hydrocarbon generation (Chowdhury and Noble 1988). These organic acids supplied the required protons for different mineral-formation fluid reactions creating secondary porosity. However, permeability was not significantly improved (only up to 100 md), which probably indicates an isochemical system of precipitation and dissolution. Mercury capillary pressure experiments were performed on reservoir sandstones to determine the pore-throat distribution pattern. Most of the sandstones show narrow pore-throat diameters (2-3 microns). SEM observations of textures indicate that dissolution is mainly controlled by grain surface reactions at specific sites, which implies slow fluid transport.

This project has now been expanded to include petroleum geochemistry and burial history of the Albert Formation. The enlarged mandate of the project has been make possible through the cooperation of the organic geochemistry and coal geology section of ISPG, Calgary. Rock Eval, gas chromatograph, and gas chromatograph-mass spectrometer analyses were undertaken on the C_{15+} and gasoline range (up to C_8) compounds of shales and richly kerogeneous shales from Albert Mines and Dover areas. Hydrous pyrolyses experiments were run on Albert Mines oil shale samples in closed stainless steel reactor vessels at 280 and 360°C in order to simulate petroleum generation and compare the artificially expelled oil with the oil from the Stoney Creek oil field. Since most of the interbedded shales within the oil field contain gas prone kerogen, it is believed that the reservoired oil in the oil field migrated from the south and east (Chowdhury *et al.*, in preparation). Biomarker analyses on both the naturally and artificially derived oil show enrichment in C_{28} and C_{29} steranes. Both of these compounds are characteristic of botryococcus algae, which has been observed in the Albert oil shales (King 1963).

A maturation study using vitrinite reflectance indicates that most of the shales in the subsurface have undergone maturation to or beyond the "oil window". A burial history study of the Albert Formation using thermal maturation parameters, TAI index, and reconstructed geohistory is in progress. Preliminary results suggest significant pre-Enragé erosion of the Albert Formation in Lower Millstream, Rosevale, Albert Mines, and Dover areas, probably on uplifted blocks associated with major faults.

Present work also includes study of the organic carbon, elemental sulphur, and sulphur isotope relationships to determine the extent of anoxicity, rate of sedimentation, and microbial contribution to different diagenetic processes. Chlorite chemistry and mineralogy, feldspar albitization, and distribution of calcrete profiles are also being studied.

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LITHOGEOCHEMISTRY OF THE LOWER TETAGOUCHE GROUP IN THE WOODSTOCK AREA, CENTRAL NEW BRUNSWICK*

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Rocks of the lower Tetagouche Group, in an area lying to the south and east of Woodstock, are being studied to determine the provenance, mode of formation, and tectonic history of the unit. The studied area exposes mainly Cambro-Ordovician quartzose sediments intruded by numerous mafic dykes that have been assigned a Devonian age.

Approximately 50 mafic dykes have been analysed for their major-, trace-, and rare-earth-element composition. The dykes are exclusively of tholeiitic basaltic affinity. There is strong evidence that they are part of a single cogenetic suite linked by crystal fractionation of mafic phases and plagioclase. The most primitive samples yielded convex LREE profiles similar to that of plateau basalts erupted on sialic crust. Rock specimens from several Siluro-Devonian plutonic units found in the area have also been analysed. The latter always shows a wider range of compositions and a more evolved character, leaving open the possibility that the dykes found within the lower Tetagouche are Ordovician or older.

Close to 100 samples of mudstones and siltstones from the lower Tetagouche Group have been analysed for their trace- and rare-earth-element content in order to constrain the chemical nature of their source rocks. Previous studies in the Quebec Appalachians have defined, on the basis of their REE characteristics, three broad families of detrital sediments: (1) the sediments accumulated in the initial rift complex, which show the presence of an alkaline component; (2) the sediments deposited along the passive margin, which yield compositions similar to those of the average continental crust and (3) the sediments deposited close to igneous complexes (such as exposed ophiolite segments and volcanic arcs), which yield a high level of mafic components. The lower Tetagouche sediments display a limited range of compositional variation, comparable to that of materials derived from a mature continental segment. There is little evidence for a significant input of juvenile igneous debris.

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*Contribution to the Canada-New Brunswick Mineral Development Agreement, 1984-89. Project carried by the Geological Survey of Canada.

The occurrence of competent dykes within sedimentary sequences is often considered a favourable environment for the development of secondary quartz veins and stockworks and thus, offers a potential for gold mineralization. Approximately 150 samples have been analysed for their gold content; these included pelites, sandstones, mafic dykes, and quartz veins. All samples yielded very low gold values (generally less than 2 ppb) except for 5 quartz veins (16, 45, 58, 77, 300 ppb) and two mafic dykes (16, 21 ppb). Most of the anomalous samples were collected to the south and southeast of the village of Grafton, in an area where sulphide mineralization (Dominion No. 1) was already known.

The forthcoming analytical program will focus on U/Pb dating (a) of two mafic dykes which have yielded some zircons, and (b) of detrital zircons from sandstone samples, with the objective of placing some constraints on the depositional age of the lower Tetagouche Group.

URANIUM METALLOGENESIS IN GRANITIC ROCKS OF THE MIRAMICHI ANTICLINORIUM*

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Investigation of uranium metallogenesis in the granitic rocks of the Miramichi Anticlinorium is continuing. In the final stage of this investigation, the W-Sn-Mo-bearing post-Acadian granitic rocks of the Burnthill, Dungarvon, Trout Brook, and Rocky Brook plutons were examined with respect to their potential for uranium mineralization by using integrated geological, geochemical, and geophysical data.

These granitic plutons were emplaced at shallow depth in the crust 380 Ma ago, and have sharp, strongly discordant contacts with the country rocks. They are formed of four textural phases; porphyritic melanocratic granite (older), porphyritic granite, equigranular granite, and late-stage pods and dykes of granite porphyry, aplites, and granophyre. Uranium anomalies are predominantly associated with the equigranular granite and with the late-stage granitic pods and dykes.

Geochemically, the granitic plutons are very evolved (SiO_2 greater than 75 wt. %). They have remarkably higher SiO_2 and Na_2O and lower TiO_2, CaO, MgO, and P_2O_5 concentrations relative to averages of these oxides in normal granites. Among the trace elements, Rb, Y, Ta, Zn, and W show higher concentrations than global averages.

Regional geochemical and geophysical data suggest that the granitic plutons are highly anomalous in terms of U content. Furthermore, these plutons are associated with a strong negative Bouguer gravity anomaly and lack well-defined magnetic anomalies - features observed in 'uraniferous' granites elsewhere. The centre of the negative Bouguer gravity anomaly coincides with the highest eU anomalies on the airborne gamma-ray spectrometry maps. These anomalies are, in turn, associated with areas of hydrothermal activity and W-Sn-Mo mineralization.

The existing data support a combination of magmatic and hydrothermal processes for U (and associated metals) concentrations in the plutons. Both U and Th increase curvilinearly with the increase in SiO_2 content of the rocks. This type of distribution may have resulted from magmatic differentiation, where both U and Th increased gradually during magma crystallization, and by post-magmatic hydrothermal activity where both U and Th are partitioned into the aqueous fluid. The Th/U ratio in the granitic rocks decreases as the amount of SiO_2 increases. This feature is, in general, unusual but has been reported for the uraniferous granites of the South Mountain Batholith in Nova Scotia. This phenomenon can be attributed to preferential enrichment of U relative to Th with the degree of differentiation of the rocks.

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*Contribution to the Canada-New Brunswick Mineral Development Agreement, 1984-89. Project carried by the Geological Survey of Canada.

GEOCHEMISTRY OF GOLD IN TILL, NORTHERN AND CENTRAL MIRAMICHI ZONE AND ITS VICINITY, NEW BRUNSWICK*

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A series of geochemical analyses for till samples collected from the northern and central parts of the Miramichi Zone and its vicinity have recently been completed as GSC Open Files (Lamothe 1988; in press). For the sake of readibility, and on the basis of local geology, the area under investigation has been divided into subzones. The northern subzone is underlain primarily by the rocks of the Tetagouche Group, the Elmtree Inlier, and the northern extension of the Chaleur Zone. This is the area where gold exploration has been concentrated in the past. In the central subzone, granitic terrains constitute an important part of the underlying bedrock. Major structures such as the Catamaran and Bamford Brook faults transect this area, and are potentially gold bearing.

Geochemical analysis of this first series of till samples indicates that the surficial till can outline some trends in the geochemical signature of the underlying bedrock. In the above reports, 1553 gold analyses are released, 254 of which have been used as blind duplicates. Of these, 76 samples have returned more than 9 ppb of gold (max = 81 ppb Au) but only a few of these were adequately reproduced. Gold abundance in till sampled over the Discovery Zone at Elmtree is at the 1000 ppb level. There, reproducibility was better but not fully satisfactory. A shallow drilling project was carried out across the Elmtree and Millstream breaks, with one sample returning 1035 ppb Au. This value was reproduced at 1065 ppb Au. The sample was collected slightly east of the Hickey showing. This site may be located over gold-bearing bedrock. It is concluded that, using current techniques, the reproducibility of gold is very poor. Values exceeding the detection limit should be interpreted as indicating the presence of gold in the split analyzed, with the value itself reflecting the size of the gold grain or the abundance of gold in an unknown mineral phase. At the Discovery Zone (Elmtree) a strong correlation is found between Au and Sb, but this correlation does not seem to be regionally widespread. When occurrence of gold is superimposed over Sb abundance (Lamothe 1988; Pronk and Lamothe 1988) elevated values of both elements are found to follow the Elmtree Break. This assemblage is not observed in the central subzone (Figure 30) where gold occurs in clusters, in the vicinity of

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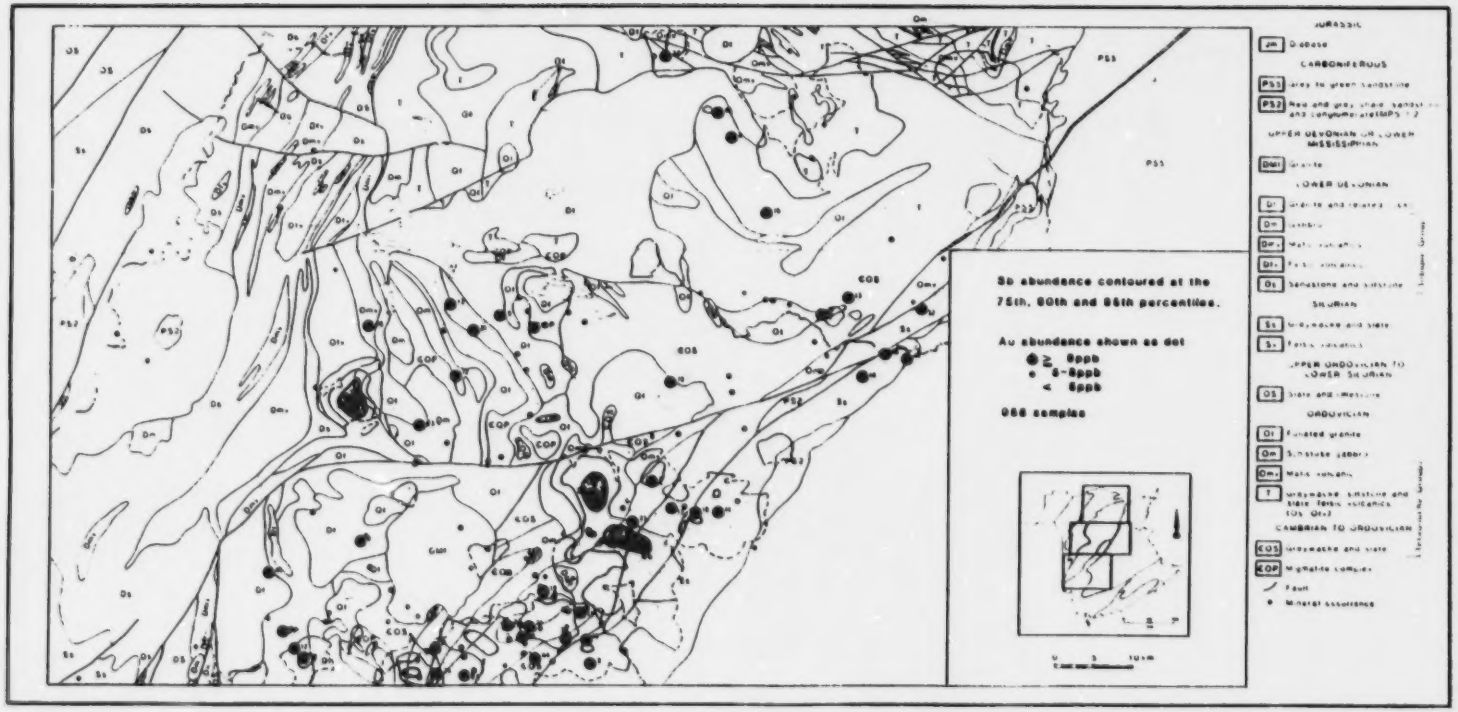

FIGURE 30. Au and Sb abundance in central Miramichi subzone.

the Devonian intrusives, and close to the fault system located in the eastern part of the area. Strong correlation between these elements is restricted to the central part of the Dungarvon granitic pluton and along its southeastern edge where it is associated with high tin values (up to 300 ppm Sn, in clay fraction of till). Those relations are also found in statistical factor analysis of the data. The correlation between Au and Sb is thought to depend on primary lithogeochemical assemblages as well as on the erratic reproducibility of gold.

It is concluded that, in the absence of visible gold, follow-up studies should be initiated when a cluster of reproducible anomalous gold values has been delineated.

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THE RELATIONSHIP BETWEEN THE ELMTREE AND MIRAMICHI TERRANES*

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The various nappes that make up the Ordovician Elmtree and northern Miramichi terranes were mapped in greater detail during the past summer. The geologic relationship between these terranes was investigated thoroughly. Detailed litho-geochemical analyses of the mafic vocanic rocks by Dr. J. Winchester of the University of Keele proved useful in distinguishing between mafic rocks of different tectonic settings. The contacts between the nappes are characterized by relatively narrow zones of phyllonites and mylonites.

The Elmtree terrane is divisible into at least three major nappes. The lowermost nappe consists of thin-bedded, grey phyllite and quartz wacke, red Fe/Mn-rich slate and minor dark green basalt. These rocks were previously mapped as the Elmtree Group. The lowermost part of this nappe has been dated by conodonts as middle to late Arenigian (G.S. Nowlan, personal communication, 1988). The overlying, middle nappe consists of dark grey lithic and volcanic wacke, pebble conglomerate, maroon siltstone, alkali pillow basalts, pyroclastics and chert. Graptolites and conodonts indicate a Llandeilian to Caradocian age for the uppermost part of this thrust sheet. The uppermost nappe comprises layered gabbro, sheeted dykes, mid-oceanic-ridge-type basalts (MORB) and plagiogranite that represent a fragment of oceanic crust. Zircons from the layered gabbroic part of this dismembered ophiolite yielded a preliminary age of 463$\pm$2 Ma (R.W. Sullivan, personal communication, 1988).

The northern Miramichi terrane can also be divided into several nappes. The uppermost nappe consists of MORB volcanics, like those in the uppermost nappe of the Elmtree terrane, underlain respectively by mylonitic gabbro and by glaucophane schist. Tentative restoration of the dextral movement on the Rocky Brook-Millstream fault system, using Late Silurian/Devonian gabbro and conglomerate markers suggest that the nappes in the Elmtree terrane were at one time continuous with those in the Miramichi terrane.

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*Contribution to the Canada-New Brunswick Mineral Development Agreement, 1984-89. Project carried by the Geological Survey of Canada.

MAFIC-ULTRAMAFIC ROCKS IN NEW BRUNSWICK AND THEIR PLATINUM-GROUP ELEMENT POTENTIALS*

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Investigations on the platinum-group-element (PGE) potential of the mafic and ultramafic plutonic rocks in the New Brunswick Appalachians, begun in the summer of 1985, are nearing completion. Detailed petrological and geochemical studies included the St. Stephen, Portage Brook, Goodwin Lake, and Mechanic Settlement** plutons, the Ordovician subvolcanic mafic intrusive rocks in the Bathurst Camp, and the intrusive rocks in the Elmtree Group (Figure 31). Reconnaissance studies were carried out on numerous other mafic intrusions in the province.

The Mechanic Settlement intrusion occurs in the Avalonian terrane, a late Precambrian microcontinent. The St. Stephen, Goodwin Lake, and Portage Brook plutons occur in Ordovician terranes representing the western margin of this microcontinent. The subvolcanic mafic intrusions in the Bathurst Camp and the Elmtree Group are believed to be remnants of an oceanic crust that existed during Ordovician time. A small lens-shaped ultramafic body occurring in the Elmtree Group represents a fragment of the upper mantle portion of this oceanic lithosphere.

The St. Stephen, Goodwin Lake, Portage Brook, and Mechanic Settlement plutons have many comparable lithological and structural features despite the differences in age and tectonic setting. One common characteristic of economic interest is the presence of magmatic sulphide accumulations. The St. Stephen, Goodwin Lake, and Portage Brook sulphides are depleted in PGE whereas those from the Mechanic Settlement pluton have high PGE concentrations (Figure 32). No significant PGE concentrations were obtained from other intrusions that were regarded as possible hosts for hydrothermal and magmatic, magnetite-ilmenite mineralization (Paktunc 1987).

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*Contribution to the Canada-New Brunswick Mineral Development Agreement, 1984-89. Project carried by the Geological Survey of Canada.

**An improper name, "the Mechanicsville intrusion", used in previous publications (i.e., Paktunc 1987, Paktunc 1988a, Paktunc 1988b) is replaced by "the Mechanic Settlement intrusion".

Figure 31. Location map showing distribution of mafic and ultramafic rocks with respect to tectonostratigraphic terranes. (after Fyffe and Fricker 1987).

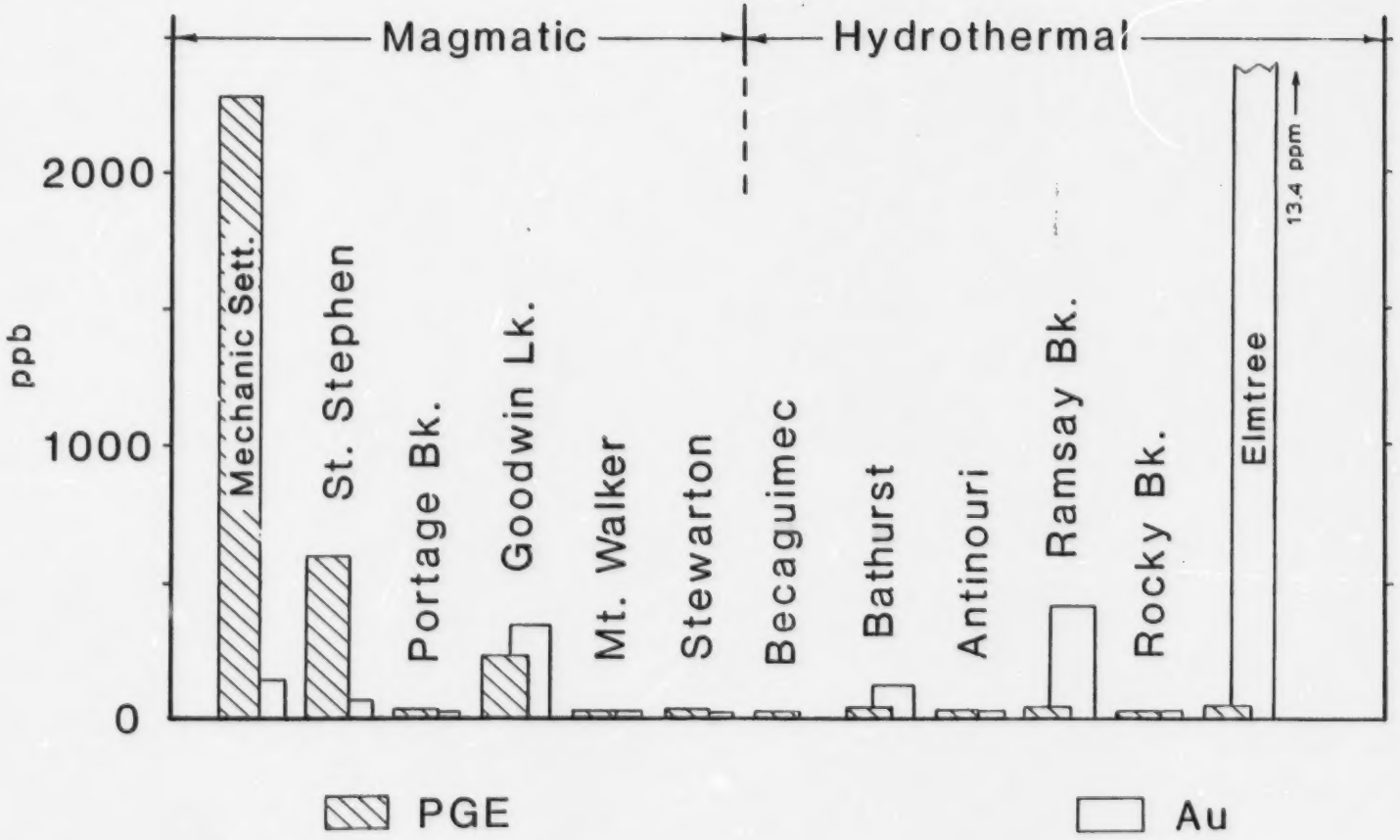

FIGURE 32. Bar chart displaying maximum concentrations of platinum-group elements and Au in the intrusions studied.

Low PGE concentrations in sulphides associated with the St. Stephen, Goodwin Lake, and Portage Brook plutons are explained by equilibration of the immiscible sulphide melt with a low proportion of silicate magma. Parental magmas to these intrusions might have been sulphur saturated before leaving the source region. An early fractionation of sulphide from the magma while en-route to the upper crustal levels or immediately after it entered the magma chamber are the other possible causes for the PGE depletion. In the case of the latter possibility, existence of undiscovered sulphide concentrations with enriched PGE would be likely. Massive to semi-massive sulphide accumulations in the St. Stephen and Goodwin Lake plutons resulted from local assimilation of the country rock containing iron sulphides.

The PGE mineralization in the Mechanic Settlement pluton was discovered in 1987 following reconnaissance mapping. The lenticular intrusion, which occurs in the Coldbrook Group volcanic and sedimentary rocks, consists of peridotite, picritic troctolite, troctolite, olivine gabbro, gabbronorite, and pyroxenite. Field studies indicate the presence of at least three major cyclic units. The PGE mineralization is associated with a feldspathic peridotite that forms the base of the lowermost exposed cyclic unit in the southwestern portion of the intrusion. To date, one platinum-group mineral, vysotskite (PdS) has been identified. Proton microprobe analyses indicate the presence of up to 63 ppm Pt, 16 ppm Pd, and 152 ppm Ag in chalcopyrites.

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AEROMAGNETIC, GRADIOMETER, VLF SURVEY BATHURST, NEW BRUNSWICK, 1986-1987*

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A combined aeromagnetic total field-gradiometer-airborne VLF survey of an area southwest of Bathurst, N.B. was flown under contract to the Geological Survey of Canada as a contribution to the MDA. A sketch of the survey area is shown in Figure 33. The contract was awarded to Geophysical Surveys Inc. of Quebec City and the survey flown in the period October 12, 1986 to April 12, 1987. The gradient field was measured by two Caesium vapour magnetometers, each with a resolution of .005 nanoteslas, separated by 2 m and suspended 30 m below a helicopter. A mean elevation clearance of 150 m was maintained with a flight line separation of 300 m. VLF total field and quadrature, using signals from Cutler, Maine and Annapolis, Maryland, were recorded with a Herz Totem-2a receiver mounted on the helicopter.

Survey output is in the form of 1:20 000 aeromagnetic total field and gradiometer contour maps and 1:50 000 magnetic anomaly and gradiometer colour interval maps. The VLF total field and quadrature profiles are printed on the back of the magnetic anomaly and gradiometer colour interval maps respectively in such away that they can be viewed jointly with the magnetics on a light table. In addition the digital data are available for purchase from the Geophysical Data Centre, Geological Survey of Canada for further processing and interpretation.

Magnetic anomaly patterns can be used to extend magnetic units under sedimentary cover and to refine geological boundaries. The gradiometer trace is particularly effective for the latter purpose as the zero gradiometer contour tends to lie directly above a magnetic contact in northern latitudes. For New Brunswick, this contour will be slightly offset due to the inclination of the earth's field, the effect of remanent magnetization and the interference from adjacent sources. VLF anomalies are associated with both contrasts in conductivity between rock units and cultural features.

Magnetic patterns recognized in the survey area can be correlated with Devonian sediments, mafic and felsic volcanics, granites, gabbros, and diabase, and Ordovician sediments of the Tetagouche Group. Magnetic anomalies are associated with the Devonian volcanics, granites, and gabbros, with the most intense anomalies corresponding to mafic volcanics. Analysis

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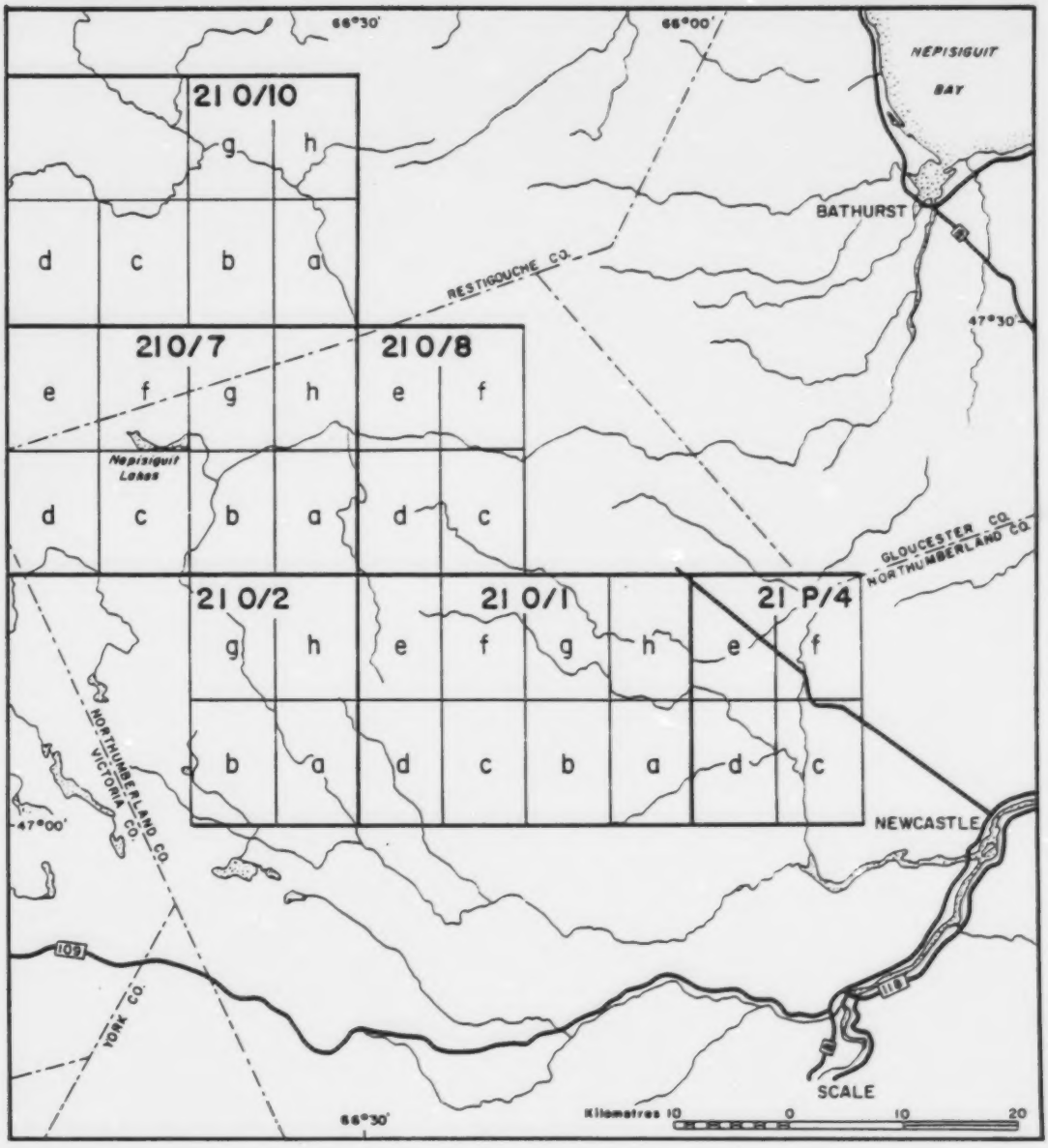

FIGURE 33. High-resolution aeromagnetic total field/gradiometer VLF survey 1986/87 - Bathurst, New Brunswick.

of these patterns indicates that the boundaries of the units can be modified considerably from those shown on the published geological map (Davies 1979). Detailed analysis of the magnetic and VLF anomalies should prove to be useful for enhancing the mapping and understanding of the complex geology in this area.

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VOLCANOLOGICAL STUDIES OF THE EARLY DEVONIAN COASTAL VOLCANIC BELT OF SOUTHWESTERN NEW BRUNSWICK*

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A belt of volcanic and sedimentary rocks is exposed along the coast of Passamaquoddy Bay, southwestern New Brunswick. This sequence was correlated with the Early Devonian Eastport Formation of Maine (Pickerill and Pajari 1976) and comprises a 125 km^2 area of the coastal section of the Mascarene terrane of Fyffe and Fricker (1987). These rocks were intruded to the north by the Saint George Batholith and are overlain unconformably to the south by the Upper Devonian Perry Formation (Figure 34).

The purpose of this study is to determine the chemical and physical volcanic evolution and economic potential of this volcanic belt. Field work on the eastern and lower part of the section was completed during the summers of 1984, 1986, and 1987. Mapping of the western and upper part of the section was completed during the 1988 field season (Figure 34). Detailed mapping was done on 1974 and 1984 series aerial photographs at 1:10 000 scale. Well-exposed stratigraphic sections were described on a bed-by-bed basis (Van Wagoner 1984, 1986; Van Wagoner et al. 1987; Van Wagoner and Fay 1988). The rocks generally young to the west.

The lower part of the section comprises an approximately 3.5 km thick bimodal and subalkaline sequence of interbedded rhyolitic and basaltic flows and pyroclastic rocks. Rhyolitic rocks are volumetrically most important. The basaltic units form flow, scoria cone, phreatomagmatic tuff cone, and peperitic breccia deposits. The felsic units were emplaced as welded and nonwelded air-fall, ash cloud, ground- and base-surge, and pyroclastic-flow deposits as well as lava flows and domes. There are 3 cycles of mafic/felsic volcanism. The sedimentary rocks are mostly littoral deposits and commonly contain basaltic and rhyolitic glass shards. Sedimentation was concommittant with volcanism and there are no marked periods of volcanic quiescence (Van Wagoner et al. 1987, 1988).

The upper part of the section records the waning phases of volcanism. It comprises interbedded red and green, littoral and subaerial sedimentary rocks; thick, tabular, and highly amygdaloidal basaltic lava flows; and rare tuffs and tuff breccias. These rocks are intruded by rhyolitic and possibly

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*This work was funded by the Canada-New Brunswick Mineral Development Agreement 1984-1989 and an NSERC operating grant to N. van Wagoner.

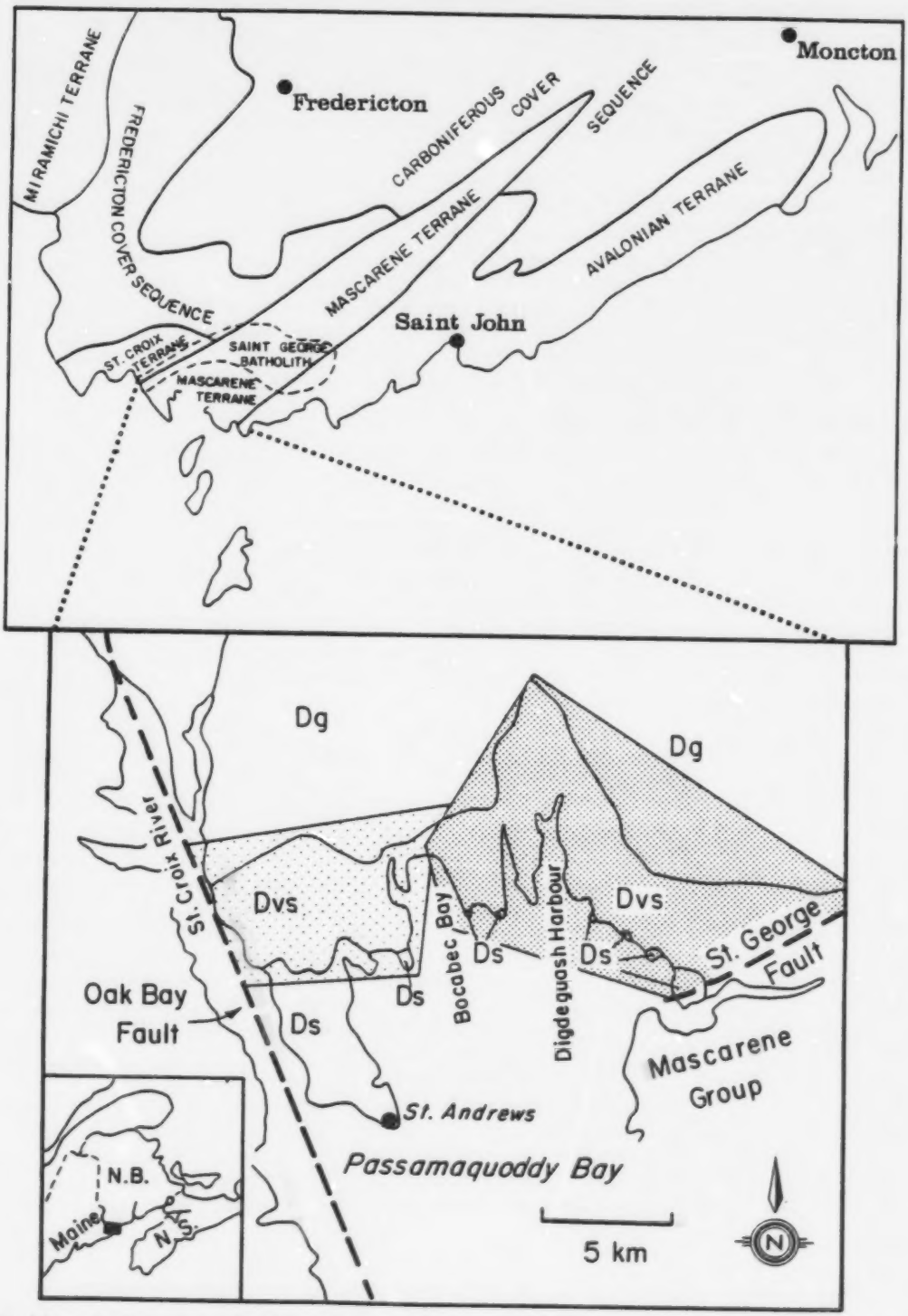

FIGURE 34. Index map of the study area showing the tectonostratigraphic terranes of New Brunswick after Fyffe and Fricker (1987) and the general geology in the vicinity of the study area after Pickerill and Pajari (1976) and Ruitenberg and McCutcheon (1980). The lower part of the section is indicated by the densely stipled area; the upper part is indicated by the open stipled pattern. Dg = Devonian granitoid rocks, Dvs = Devonian volcanic and sedimentary rocks, Ds = undifferentiated Silurian and Devonian rocks.

andesitic domes, and diabase dykes, sills, and plugs. In contrast to the lower part of the section, most of the extrusive volcanic rocks are basaltic, and sedimentary rocks dominate the sequence.

Future plans include determination of; 1) the stratigraphy and facies relationships of the lower part of section, 2) the relationship between the upper and lower sections, 3) the palaeotectonic setting of the volcanic belt, 4) the lithogeochemistry and chemical stratigraphy and petrogenesis of the rocks, and 5) the mineral potential of the area based on lithogeochemical studies and observed patterns of alteration.

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APPLICATION OF GEOGRAPHIC INFORMATION SYSTEMS TO DATA INTEGRATION STUDIES IN NORTHEASTERN NEW BRUNSWICK*

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One of the important tasks for government geological surveys is to provide regional mineral resource assessments to assist in formulation of government policy. These assessments bring together all geoscience data known for an area, focussing on areas of mineral potential. This provides a stimulus to exploration activity and improves the knowledge base for the selection of exploration targets. In Canada, resource assessment is mainly a government task, whereas the more site-specific mineral exploration is carried out by the private sector. The data types and procedures adopted in both cases are very similar.

Geoscientists and explorationists use various types of spatially-indexed data (e.g., geophysical, lithological, geochemical, remotely sensed, topographic, etc.) in their assessment of mineral resources. These data have normally been portrayed in hard-copy format on specific-purpose or "thematic" maps. Traditionally, the integration of spatial data has been accomplished by superimposing several thematic maps using a light table and creating composites. The modern trend is toward acquiring and storing spatial data in digital formats that are processable by computers. The application of computer technology to spatial data can provide the geoscientist with a powerful tool for analysis that greatly extends the capabilities of conventional thematic maps. Computer systems of this type have been generically labelled Geographical Information Systems (GIS).

The Mineral Resources Division of the Geological Survey of Canada has recently established a new computer facility for spatial integration of geoscience data packages. At the core of this facility are two Canadian software packages**, both running on microcomputers, one for analysing remote sensing and other types of digital imagery, the other for combining and analysing geographically co-registered maps.

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*Contribution to the Canada-New Brunswick Mineral Development Agreement, 1984-89. Project carried by the Geological Survey of Canada.

**EASI/PACE image analysis system - PCI, Incorporated, Toronto; and SPANS spatial analysis system - TYDAC Technologies Inc., Ottawa.

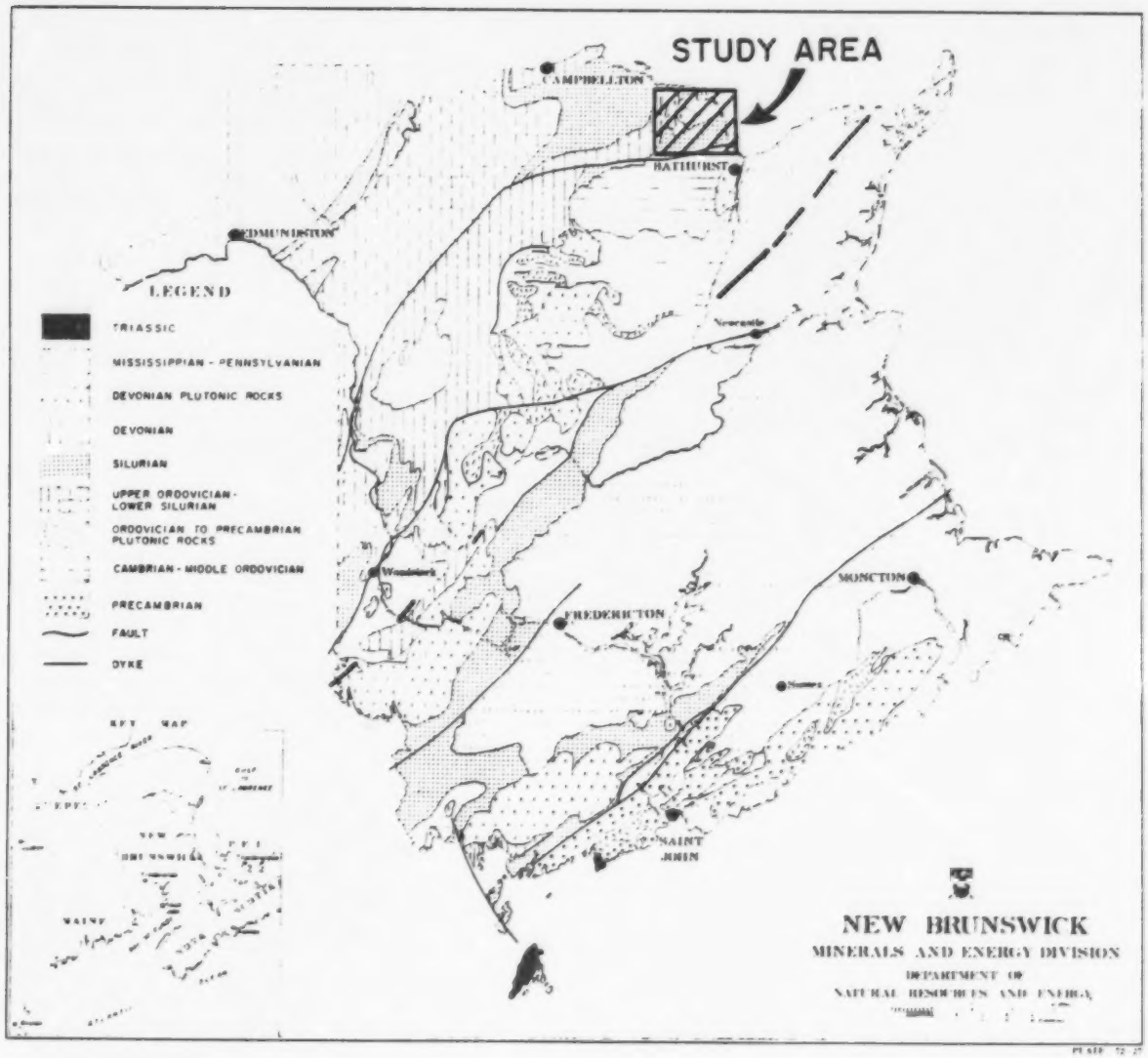

FIGURE 35. Location map showing study area.

Peripheral devices include a digitizing table for input of point, line, and polygon data from maps; a tape drive for input of various types of digital images; an optical WORM drive (Write Once Read Many times) for archiving and backup; and an ink-jet plotter for hardcopy output.

In the first year of operation, this facility has been used for a variety of data integration projects, including gold assessment in northeastern New Brunswick, discussed here, using regional geological, geophysical, geochemical, mineral occurrence, and remote sensing data. This study is part of the Canada-New Brunswick Mineral Development Agreement.

The study area, northwest of Bathurst, New Brunswick encompasses a region of 30 x 30 km (Figure 35). The geology of the area comprises three major elements - the Miramichi Massif, the Elmtree Inlier and the Matapedia Basin, and has been described in Fyffe and Noble (1977).

The structure of the study area is dominated by the northeast-trending Rocky Brook-Millstream Fault system. A cluster of base-metal and precious-metal occurrences lies along this fault system and in an area extending to the western margin of the Antinouri Lake granite stock. Over 65 occurrences are known in this region. This part of New Brunswick has been the object of much renewed exploration interest in the last three years resulting from the recent discovery of several new precious-metal occurrences.

One of these relatively new occurrences, the Elmtree Au deposit owned by Corona Corporation, was chosen as a model for this study. The property is located in the Alcida-Madran area, some 30 km northwest of the city of Bathurst. Gold at Elmtree is hosted by a hydrothermally altered gabbroic sill emplaced near the faulted contact between the Ordovician Elmtree Group and Silurian Chaleurs Group. Varying proportions of disseminated arsenopyrite, pyrrhotite, and pyrite with minor chalcopyrite, stibnite, sphalerite, and galena and trace amounts of native gold are locallized within a broad zone of intense shearing, fracturing and deformation, locally referred to as the Elmtree Fault.

The project objectives are: a) to compile in digital format and integrate a variety of geoscience data sets available for the study area using a desktop, microcomputer-based GIS; b) to determine geologic characteristics that are considered relevant to predicting the location of mineral occurrences in general and gold mineralization similar to the Elmtree deposit in particular; and c) to develop a modelling function which would predict areas favourable to the occurrence of this style of gold mineralization.

Types of geoscience data compiled and digitized for the study area include:

i. Geology and Mineral Occurrences: The bedrock geology map was digitized by raster scanning at a scale of 1:50 000 reduced from 1:20 000 maps compiled by Philpott (1987a, b).

The original map contained 21 different units that were grouped into 14 classes to facilitate display in colour. The locations of all known mineral occurrences in the study area were obtained from the CANMINDEX data base (Picklyk et al. 1978).

ii. Regional Geochemistry: Two sets of geochemical surveys were input to the integration study, a till survey, and a stream sediment survey. Four hundred and ninety-two till samples were analysed for 17 elements (M. Lamothe, personal communication, 1988), while 498 steam sediment samples were tested for concentrations of 11 elements (Boyle et al. 1966).

The till data were converted from point data into a thematic map using an interpolation routine supplied with the GIS. The stream-sediment data were converted to map form using the catchment basins upstream from each sample point as the area of influence. A catchment basin map was raster scanned as above; for each element, the basins were assigned element concentrations according to the average of values found within each basin.

iii. Remote Sensing Imagery: A LANDSAT Thematic Mapper (TM) image was obtained for this region, and used to identify areas spectrally similar to the zone around the Elmtree property (Rencz and Watson, in preparation). The rationale for this work is that vegetation around a mineralized site may be spectrally different from that growing in unmineralized areas. The differences can be due to several factors such as species associations, or vegetation stress.

The image was first geometrically corrected to remove the warped projection resulting from the rotation of the earth beneath the satellite. This was carried out using the microcomputer-based EASI/PACE image analysis system. The same system was then used to characterize the spectral response in the area around the Elmtree property. In the final step, a new interpreted image was generated, showing the areas with a similar spectral response to Elmtree. The resulting spectral anomaly image was transferred to the SPANS GIS.

iv. Lineaments: Lineaments interpreted from LANDSAT and geologic data were hand digitized and incorporated into the GIS. From earlier work (Watson and Rencz 1988), two groups of lineaments trending between 22-45 degrees (ENE) and 145-167 degrees (NNW) were selected because they are spatially

correlated with known mineral occurrences. These lines represent geologic contacts and mapped faults derived from existing maps, in addition to linear patterns interpreted from the LANDSAT image reflecting subsurface structure.

v. Airborne Geophysics: Information derived from airborne geophysical surveys conducted for the GSC as part of the current MDA showing radiometric potassium, equivalent thorium, equivalent uranium, and their ratios, were brought into the data base and co-registered.

Some selectivity is inherent in data integration, especially in the choice of input variables that will be considered relevant to the model. Not all of the information available to the mineral explorationist or the resource analyst is useful in defining specific target areas. For example, the file for till geochemistry contains data on the abundances of 17 chemical elements; however, only 3 elements (Au, As, and Sb) were used in the integration model as they were considered the best indicators of this style of gold mineralization in northern New Brunswick. Similarly, the original stream-sediment geochemistry contained data for 11 elements and only the values for As were input into the system.

The most important task in integrating data sets is to devise a model that best describes the relationship between the input variables and effectively predicts the occurrence of the parameter in question. This model can be derived by several experts assigning weights to the input variables. This case study relied on a combination of the two approaches.

A new method using conditional probabilities and Bayes Rule was used to develop a weighting scheme for combining individual map layers to produce a map showing gold potential. This method is discussed in Agterberg et al. (in press), and Bonham-Carter et al. 1988), as applied to gold exploration in the Meguma Zone of Nova Scotia.

Probabilities for the various input variables were computed based on their ability to predict the location of known gold-bearing mineral occurrences within the study area. The values provide a measure of the correlation between a given input variable (e.g., gold abundances in till samples) and the location of auriferous mineral occurrences.

The calculated coefficients for each of the input variables were then related in a modelling equation to define portions of the study area with high probabilities of containing gold mineralization similar to the Elmtree occurrence. The equation was evaluated for the "unique conditions" map generated by SPANS that combined the information from all of the individual thematic maps and data files used as input for the model. The resulting map portrays the probability of locating a similar mineral occurrence for the entire study area. Generally, areas

of high probability reflect known auriferous mineral occurrences or can be explained as contamination effects from active or past mining operations in the area. In this regard, the modelling equation is deemed successful in that it accurately identifies known targets. The application to resource assessment requirements to provide some prediction of the known or potential mineral worth of a given region is illustrated here. There are some additional areas of high probability that are not clearly linked to known mineralization or contamination and could therefore represent viable exploration targets.

In conclusion, GIS affords a significant new tool in both research and applied areas of geoscience. New forms of spatial data representation, modelling, and interpretation are now possible. The development of low-cost, user-friendly, microcomputer-based GIS software is making spatial data integration easier. Furthermore, new algorithms for combining maps for estimates of mineral potential show promise. Although the gold-potential map for this area of northern New Brunswick is as yet untested, it certainly suggests that there are several areas where favourable conditions co-exist, yet no gold mineralization has been reported.

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GEOLOGICAL, GEOCHEMICAL AND ISOTOPIC STUDIES OF GRANITIC ROCKS IN NEW BRUNSWICK*

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This project, which was initiated in 1985, has three major components: (1) geological mapping of the northern end of the Central Plutonic Belt; (2) a detailed petrographic and geochemical study, including trace elements of economic interest (e.g., Sn, W, Mo, Ta, U, Th, Cu, Pb, Zn, Au, REE), of 326 representative samples of all the Palaeozoic granites in New Brunswick; and (3) isotopic tracer and geochronological dating studies of granitic rocks in New Brunswick. This project provides data important for petrologic, tectonic, and metallogenic models in the New Brunswick Appalachians.

(1) Geologic Mapping: Geology of the map area in the Central Plutonic Belt described by Whalen (1987) has just been released as an open file map with marginal notes at 1:50 000 (Whalen 1988) and will also be published in 1989 as a coloured A-series map at 1:100 000 scale. The mapped area (Figure 36), located between 47°00', 47°28' latitude and 66°15', 67°00' longitude, covers an area of approximately 2300 km^2. It includes portions of NTS sheets 21 O/1, O/2, O/7, and O/8 and NBDNR 1:15 840 geological map sheets K10, K11; L8, L9, L10, L11; M8, M9, M10, M11; and N9, N10. Additional outcrop data compiled from these sheets have been included on this map. Over the last ten years, many new logging roads have been built, providing improved access. All the new roads have been included on this map, a feature that should increase its usefulness for mineral prospecting and exploration.

The oldest rocks exposed in the area (Unit 1) are part of the Tetagouche Group, a thick sequence of shale, greywacke, quartzite, and bimodal volcanics. These rocks were intruded by a suite of granitic rocks of Ordovician age (Bevier, this volume) prior to regional metamorphism and polydeformation. Subsequently, Siluro-Devonian clastic sediments and bimodal volcanics, which underlie the northwestern part of the map area, were deposited. All of these rocks were intruded by a number of suites of Siluro-Devonian plutonic rocks ranging in composition from mafic to felsic (Bevier and Whalen, in press).

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*Contribution to the Canada-New Brunswick Mineral Development Agreement, 1984-89. Project carried by the Geological Survey of Canada.

grained, mafic-poor, biotite granite. The Meridian Brook (Unit 2b), Serpentine River (Unit 2d) and Mullin Stream Lake (Unit 2e) granites, which are lithologically and chemically very similar, consist of orange to beige, fine- to coarse-grained, equigranular, biotite-muscovite granite. Muscovite, which is concentrated along foliation planes, is probably metamorphic, but the presence of garnet in some samples suggests a primary peraluminous character. The Sweat Hill granite (Unit 2c) is a quartz and feldspar porphyritic, biotite-muscovite granite. It varies from a coarse-grained, nearly equigranular granite to a high-level porphyry. At the southern end of the map area, a feldspar porphyritic to megacrystic granite (Unit 2f) is considered to be part of the Fox Ridge granite.

The western portion of the map area is underlain by a sequence of northeast- to southwest-striking, sedimentary and bimodal volcanic rocks of Siluro-Devonian age (Unit 3). In the southwest part of the map area, the northern end of the Redstone Mountain granite (Unit 4) crops out. This granite closely resembles the alkaline granite of the Mount Elizabeth suite (Unit 7e). The composite Mount Elizabeth intrusive complex at the north end of the map area has been subdivided into a mafic suite (Unit 5) comprising troctolite, diabase, and gabbro, an eastern peraluminous biotite granite (Unit 6), and a western alkaline granite suite (Unit 7) comprising fayalite-hedenbergite syenite, quartz monzonite, hydrid rocks,. aplite and alkaline granite. Eastern and western granitic suites are separated by a zone of fine-grained, felsic and mafic intrusive rocks. Field relationships, such as cuspated, irregular chilled contacts of mafic against felsic rocks, pillowed mafic rock in granitic rock and evidence of interaction to produce intermediate or hybrid composition rocks, reflect magma-mixing and suggest that felsic and mafic components of the suite are contemporaneous.

The North Pole Stream granite suite consists predominately of medium- to coarse-grained, equigranular to K-feldspar porphyritic biotite granite (Unit 8c). The suite includes older biotite granodiorite (Unit 8a), amphibole-bearing gabbro and diorite (Unit 8b), and younger fine- to medium-grained muscovite-biotite and biotite granite (Unit 8d), which in places contains muscovite pseudomorphs after, and relict, cordierite. For simplicity, gabbroic rocks northwest and west of Long Lake, including the Blind Lake gabbro, have been included in Unit 8b.

The Miramichi granite (Unit 9), which is located in the northeast part of the map area, is lithologically and chemically similar to the Mount Elizabeth peraluminous granite (Unit 6) and the North Pole Stream granite (Unit 8c), both of which have identical U-Pb ages (Figure 36).

In the area of Long Lake, various exploration programs have been undertaken to evaluate base-metal and U mineralization associated with high-level, highly fractionated roof-zone phases

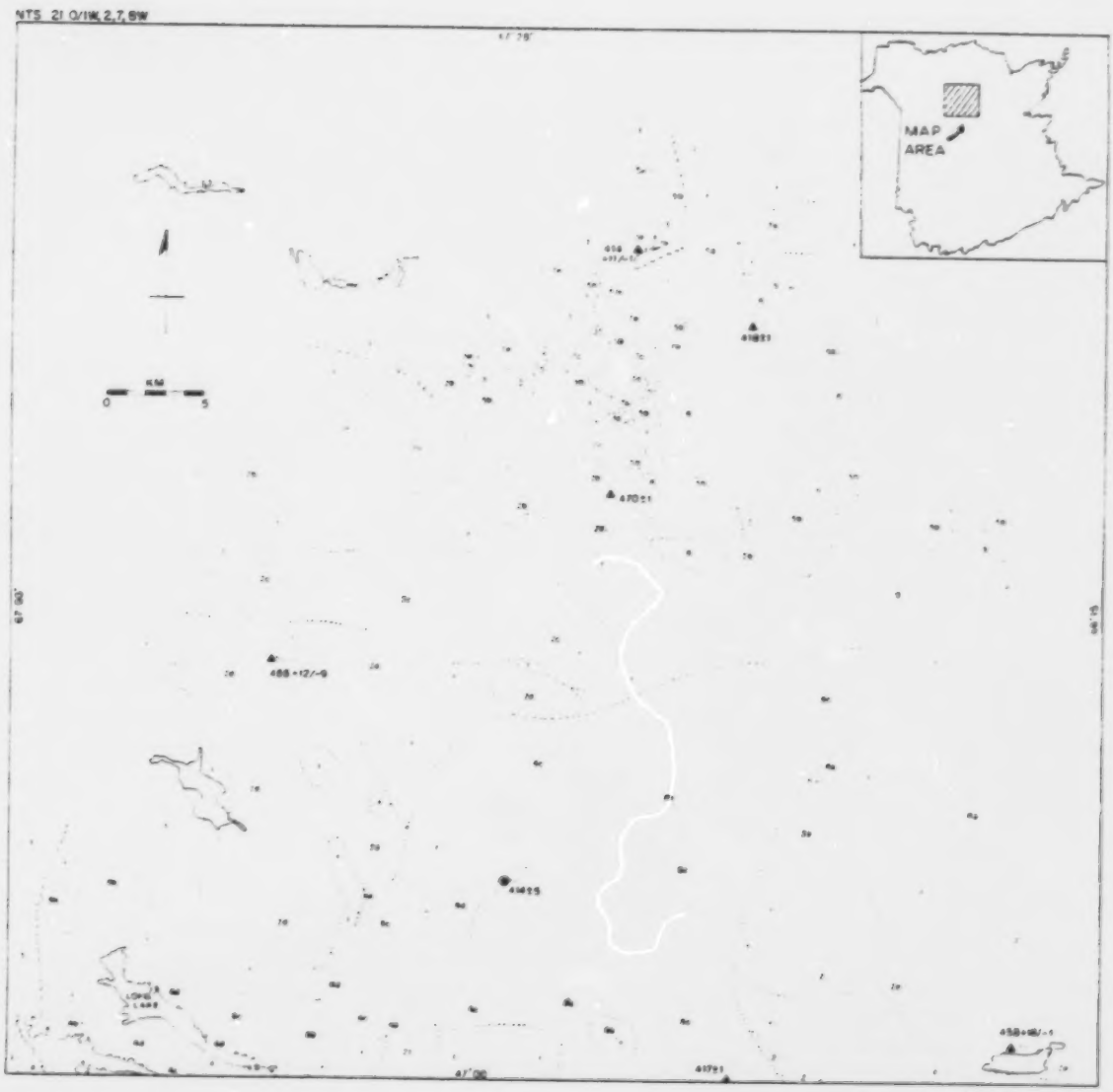

FIGURE 36. Simplified geological map of a northern portion of the Central Plutonic Belt of New Brunswick, after Whalen (1988b).

Ordovician granites form six main, and a number of smaller bodies, most of which are elongated parallel to regional structural trends. Deformation in the granites is quite heterogeneous and indicates a considerable degree of flattening. The Popple Depot granite (Unit 2a) is a reddish pink to beige, fine-

LEGEND

SILURIAN

9 - Miramichi Granite

(NOTE - Units 4 to 9 are of similar age)

North Pole Stream Granite Suite

8a - m.g.-c.g. biotite granodiorite

8b - gabbro, diabase, and diorite

8c - m.g.- c.g. biotite granite

8d - f.g.- m.g. muscovite-biotite and biotite granite

Mount Elizabeth Intrusive Complex

Alkaline Granite Suite

7a - hybrid intrusive rock

7b - syenite

7c - quartz monzonite

7d - aplite

7e - alkaline granite

6 - f.g.-c.g. biotite granite

Mafic Suite

5a - Portage Brook troctolite

5b - diabase and gabbro

4 - Redstone Mountain granite

3 - clastic sedimentary and bimodal volcanic rocks

ORDOVICIAN

2a - Popple Depot granite

2b - Meridian Brook granite

2c - Sweat Hill granite

2d - Serpentine River granite

2e - Mullin Stream Lake granite

2f - Fox Ridge granite

1 - Tetagouche Group

- U-Pb age (Ma +/-2 SD)

- K-Ar age (Ma +/-2 SD)

of the North Pole Stream granite. Mafic intrusive bodies at Portage Brook and Goodwin Lake have been the object of past and current exploration interest for Ni, Cu, and Pt+Pd. In the map area, potential for gold mineralization exists in (1) zones of extensive quartz veining and dyking in Tetagouche Group rocks within the Mount Elizabeth complex; (2) in pyritic stockworks at the contact between felsic volcanics (Unit 3) and alkaline granite (Unit 7e); (3) in sulphide-bearing veins with associated alteration haloes cutting the Serpentine River granite (Unit 2d); and (4) in shear zones cutting the deformed granites (Unit 2), zones which could have acted as conduits for gold-bearing fluids. Also, a greisen alteration zone containing molybdenite was recognized in the eastern biotite granite (Unit 6) of the Mount Elizabeth complex and a brecciated and silicified zone was identified in the body of alkaline granite (Unit 7e) adjacent to Mount Edwards.

(2) Petrological and Geochemical Studies: Preliminary results of petrological and geochemical work have been reported in Whalen (1986, 1987, and 1988a) and are summarized below. Other publications are in preparation.

New Brunswick granites are mainly metaluminous to slightly peraluminous and contain high Na_2O contents (generally greater than 3.7%). Within the Elmtree terrane (for terrane map after Fyffe and Fricker (1987), see Figure 28 of Bevier, this volume), the proportions of amphibole-bearing, mafic to felsic intrusive rocks are approximately equal, whereas in other terranes, felsic biotite granite is vastly predominate (greater than 80% by volume). Based on field evidence, some of the intermediate compositions present in both Miramichi and St. Croix terranes result from magma mixing between mafic and felsic compositions. Modal and chemical data indicate that most New Brunswick granites can be classified as I-type granites. However, rare muscovite-cordierite-bearing Miramichi terrane granites are S-type. Though some New Brunswick granites contain elevated values of high-field-strength elements, these elements and Ga/Al values are generally less than those characteristic of A-type granites. Unambiguous A-type granites present in New Brunswick are the Mount Elizabeth alkali granite (Figure 36) and the Welsford complex of the Saint George Batholith (Whalen 1986). Ordovician granites in Miramichi terrane contain metamorphic muscovite and garnet, are peraluminous and very felsic (SiO_2 average = 73.4, and range = (66.2-78.5)). Zircon dating and preliminary examination of geochemical data substantiate the suggestion of Whalen (1987) that these plutons are consanguinous with felsic volcanics of the Tetagouche Group. Geochemical evidence suggests that, except for Elmtree terrane where a mantle component appears to be present, New Brunswick granites are derived from continental crustal source rocks. Elmtree terrane granite may be subduction-related, whereas other New Brunswick granites formed in a within-plate or post-collisional tectonic setting.

(3) Isotopic Studies: Isotopic tracer and geochronological studies on New Brunswick granitic rocks consist of Rb-Sr and K-Ar muscovite and biotite ages on 26 samples, Nd-Sm isotopic tracer work on representative samples of all New Brunswick granites (joint project with G. Jenner, Memorial University) and common Pb and zircon U-Pb geochronological studies by M.L. Bevier. Work by M.L. Bevier is reported separately in this volume and her U-Pb zircon ages from the various intrusive units in the map area are plotted in Figure 36. The other isotopic work, which is still in progress, will be presented in future publications.

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SECTION III

UNIVERSITY OF NEW BRUNSWICK

REPORT OF ACTIVITY, DEPARTMENT OF GEOLOGY AND GEOLOGICAL ENGINEERING PROGRAM, UNIVERSITY OF NEW BRUNSWICK

H.W. van de Poll, Chairman of Department

GENERAL

The Department comprises 15 full-time faculty, 3 Post-doctoral Fellows, 2 Research Associates, 1 Professor Emeritus, 7 technical staff, 2 technical trainees, 3 secretarial staff, 10 PhD and 13 MSc resident and 3 non-resident post graduate students, (nine of whom are working on New Brunswick projects), and 70 undergraduate students (31 science majors in geology and 39 geological engineers). The Natural Sciences and Engineering Research Council supported the Department's research in the amount of $202 445 for the year and the Maritime Provinces Higher Education Commission provided $4000 for research equipment and $14 344 for building renovations during 1987-88. Research funding was also obtained from other sources. The Heath Steele Mine project was supported by funds and services from Department of Natural Resources and Energy; Energy, Mines and Resources Canada; and the Noranda Group of companies in the amount of $242 000 for the current year. Other projects were funded by Energy, Mines and Resources Canada; the University of New Brunswick Research Fund; University of New Brunswick Futures Fund; Chevron; AMOCO Canada Petroleum Company Ltd.; and others.

Ten geologists and six geological engineers graduated from U.N.B. since our last report. Like last year, this graduating class was noted by the five BSc honours, Dean's listings (three geological engineers and five geologists), and prizes awarded to its members. One of the geological engineering undergraduates, Mr. E. Whyte, won the Canadian Institute of Mining scholarship. Mr. P. Burns, a BSc geology was awarded a Natural Sciences and Engineering Research Council postgraduate scholarship. All of the graduates were employed for at least the summer. Two persons completed their PhD's and one MSc was awarded during the past year.

Members of the faculty and graduate students published approximately 50 scientific papers and abstracts.

Drs. J.P.A. Noble, J.C. White, and Professor M. Chrzanowski have returned from their sabbaticals respectively in France, the U.S.A., and British Columbia. Mr. D. Ball lectured in sedimentology during Dr. Noble's absence.

GEOLOGICAL ENGINEERING

Geological Engineering continues to be a popular program at UNB with approximately 40 undergraduates enrolled in all

years. Almost every student from first year on was employed in geological work over the summer and this in itself is expected to have a positive impact on future enrolment in the program. Several professionals from government and industry contributed to the teaching of an evening course in Mineral Resource Utilization, including: Mr. D. Ball, Mr. W. Carr, Mr. J. Chandra, Mr. G. Kooiman, Mr. W. Lockhart, Mr. S. McEwan, Mr. K. Phinney, Mr. J. Thibault, and Mr. T. Webb. The course is required as part of the Mineral Resource option and the professional involvement was well received by the students.

Between January and August, 1988, Professor M. Chrzanowski was on a study leave at the Department of Geological Sciences, University of British Columbia. While at UBC she participated in their Geological Engineering Program and prepared new laboratory problems in geological hazards for our own program at UNB.

GEOCHEMISTRY

Dr. N.J. Susak is currently on sabbatical leave at Oak Ridge National Laboratory, Oak Ridge, Tennessee, U.S.A. While on sabbatical he will be continuing his studies of cobalt solvation and metal-transport mechanisms in hydrothermal solutions. These are initial studies that will eventually be extended to determine metal transport in cobalt-nickel-arsenide ore deposits. Spectrophotometric studies with PhD graduate student, Mr. Pan, of cobalt chloro-complexes and bromo-complexes have been completed. Bromine complexes were investigated to determine the influence of bond strength on the stability of transition metal complexes. A study of the dissolution kinetics of cobalt oxide has been completed. This project demonstrated the feasibility of using an in-line spectrophotometric monitor for dissolution kinetics studies and should provide a significant improvement over the classical batch-type studies. Work on the hydrothermal solubility of cobalt oxides is continuing.

GEOPHYSICS

Dr. K. Burke and Miss. R. Comeau completed an investigation of documented seismicity in the southwestern part of New Brunswick for the period 1900 to 1961 in a contract study sponsored by the Geophysics Division of the Geological Survey of Canada. Under the same contract, Dr. Burke and Mr. A. Gerdson investigated the historical seismicity for the Saint John region. Three previously unlisted events were found for the southwestern region and five for the Saint John region. Evidence was also found for significant changes to present listings of earthquake locations, times and magnitudes in the Canadian Earthquake Epicentre File for both regions.

The April 23rd, 1988 earthquake in the Moncton region is being investigated by Dr. K. Burke in cooperation with the

Geophysics Division of the Geological Survey of Canada. An intensity survey of this event has been made and the source mechanism and its relationship to subsurface geology is being studied.

Dr. K. Burke and Mr. C. Hawkes participated in a marine geophysical survey of Passamaquoddy Bay and the near-shore region of Point Lepreau conducted by the Bedford Institute of Oceanography. Side-scan sonar, high-resolution seismic, and magnetometer profiles were run.

MINERAL DEPOSITS

Economic geology activity continued to be focused mainly on Appalachian mineral deposits with an emphasis on massive sulphides.

Dr. A.L. McAllister and Dr. H.H. Hassan are continuing their research on the uranium potential of granitic plutons in the central Miramichi Highlands. Integrated geological, geochemical, and geophysical data on the post-Acadian North Pole Pluton and its associated mineralized veins have established criteria for recognizing other favourable plutons. Use of these criteria on granites of the anticlinorium has allowed identification of the Sn-Mo-W-bearing Burnthill, Trout Brook, Dungarvon, and Rocky Brook plutons as having the highest potential for vein-type uranium deposits.

At Heath Steele Mines, a three-year project, jointly sponsored by the Federal and Provincial governments, is in its third and final year under the direction of Drs. P.F. Williams and A.L. McAllister. The object of this study is to provide a general assessment of the geological structures, define the distribution of stratigraphic layers, and ultimately, to use these data to locate additional ore reserves. Structural and stratigraphic work is being carried out by Dr. Jacob de Roo and PhD student Chris Moreton. Coordinator Mr. J.G. Torrance, in collaboration with Mr. M. Lodin, has carried out a successful analysis of satellite remote-sensing data. MSc student Mr. G.A. Alcott is currently writing his thesis, which will contribute data for the final geophysics report. Three student assistants were hired this year and trenching was carried out by sub-contractors.

Gold distribution in the Brunswick #12 massive sulphide deposit is being studied by Ms. S. LeBlanc, under supervision of Dr. D.J. Bachinski. Additional projects by Dr. Bachinski include studies on red bed copper and porphyry-copper deposits, and a CIDA-sponsored program on a carbonate-hosted zinc deposit in Thailand with graduate student Mr. B. Yokart.

Dr. P.F. Williams and graduate student Mr. W. Roberts are continuing a study of the structure of the potash in the Dennison Mine at Sussex as an aid to an improved economic assessment of its potash potential.

Dr. H.W. van de Poll is investigating the economic geology of the Permo-Carboniferous of New Brunswick, Nova Scotia, and Prince Edward Island. Emphasis is placed on the lithostratigraphy, sedimentology, physical diagenesis, and palaeoclimatic evolution of coal basins, and of the Prince Edward Island red beds for an overall evaluation of their economic potential with respect to coal, copper, uranium, natural gas, and gravel.

A project in Nova Scotia by Mr. R.J. Ryan, PhD candidate under supervision of Dr. H.W. van de Poll, is nearing completion. The stratigraphic, sedimentologic, palaeoclimatic, and other basinal factors in the numerous, sediment-hosted, copper-uranium-lead-silver occurrences of the Tatamagouche syncline are being examined. Several papers on the progress and results of this project have been presented at national conferences. His studies are currently centred on the hypothesis that the mineralized Upper Pennsylvanian-Lower Permian strata of the area represent the exposed segment of a much larger transition zone between the predominantly red Permian, and predominantly grey and red Pennsylvanian sequences. The Cu, U, Pb, and Ag minerals may have been locally concentrated around plant remains in this transition zone, following post-depositional oxidation and leaching of these elements from the overlying red beds.

Dr. J.P.A. Noble with graduate student, Mr. Ali Chowdhury is in the process of completing the MDA-sponsored project on the diagenesis of the Albert Formation. A number of papers have already been presented at national and international conferences summarizing results that are of importance to the future exploration of oil and gas in New Brunswick. A parallel project on the Stoney Creek Oil and Gas Field, carried out by research associate Mr. S. Foley and DNRE representative Mr. C. St. Peter, is nearing completion. Extensive relogging and remapping of the reservoir-sandstone units of this field and reinterpretation of the depositional history will aid in further exploration. Certain aspects have been presented orally at professional meetings.

PALAEONTOLOGY

Dr. A. Logan is continuing actuopalaeontological studies of modern hard substrate communities in the Bay of Fundy with a view to ascertaining their value for palaeoecological reconstruction in the Mesozoic. He is also working on competitive interactions of hermatypic corals in Bermuda and their significance in terms of distribution and succession of similar species in Tertiary and Pleistocene reefs.

Dr. J.P.A. Noble and his co-workers, Dr. G. Young (who graduated with a PhD in March of this year), and PhD student Mr. D.J. Lee, are continuing their studies on Palaeozoic fossil assemblages. Emphasis is placed on Silurian corals and stromatoporoids and the relation between the New Brunswick and Gaspé faunas to obtain a better understanding of coral and

stromatoporoid taxonomy, palaeoecology, and evolution. These studies also provide a more accurate biostratigraphy and aid in the reconstruction of plate movements.

Dr. R.K. Pickerill is continuing work on the structure, composition, ecology, and evolution of Silurian brachiopod-dominated communities of Arisaig (Nova Scotia). Additionally, he is studying the structure, composition, and evolution of Ordovician marine benthic communities in Quebec with Dr. T.L. Harland, and in Wales with Dr. P.J. Brenchley. He is also collaborating with Dr. M. Waden of the Queensland Museum, Australia in a study of Cambrian jellyfish from the Saint John area. He continues his extensive trace-fossil research in Spain, Portugal, Quebec, Newfoundland, New Brunswick, Alaska, Oregon, southern California, and northern Greenland. One of his PhD graduate students, Mr. D. Fillion is undertaking similar studies in Oregon and southern California.

PETROLOGY

Dr. Todd Dunn is carrying out research on the partitioning of the group IIIb, IVb, and Vb transition metals between clinopyroxene and melts with varying Mg numbers. In addition, Dr. Dunn supervised a BSc thesis by Mr. R. Benn on the petrology of late Quaternary/Holocene eruptives associated with Mt. Adams, a volcano on the west coast of North America. In September 1987, Dr. Dunn took over supervision of the UNB Geology Department XRF lab and is now producing complete major-element and limited trace-element analyses on a routine basis. In July 1988, Dr. Dunn acquired an electron microprobe which should be completely automated by the end of the year. Research plans for 1988/89 include the trace-element partitioning studies and major-element chemical diffusion studies in silicate melts.

Dr. J.G. Spray is continuing his investigations on metamorphism and melting in fault and shear zones. This is being carried out at both the field and experimental levels. Field work has centred on studies of thrust-related metamorphism beneath tectonically transported fragments of oceanic lithosphere and studies of the fault systems in New Brunswick. In addition, the igneous and metamorphic genesis of the Elmtree mafic complex of northern New Brunswick is being researched as part of Ms. P. Flagler's MSc thesis. Experimental work has focused on the application of friction-welding apparatus to the study of frictional heat phenomena in rock. The equipment enables fault movement to be simulated in terms of velocity, load (stress) and duration. Different fault rocks can be produced by this process (e.g., gouge at low power and melt at high power). The experimental technique has considerable potential for providing insight into fault dynamics and the generation of earthquakes (e.g., J.G. Spray, 1988, Contributions to Mineralogy and Petrology, **99**, 464-475). It is planned that these studies will also lead to a

greater understanding of fluid movements and consequent mineralization processes occurring in fault zones. Mr. B. Bas has recently started investigating gouge and friction melt generation in the new Friction Laboratory and Ms. L. Kennedy has commenced a project on the high-temperature alteration of rock by drag cutters.

Dr. L.T. Trembath is studying crystallization of feldspar in synthetic and natural systems. This latter project is concerned with a comparison of microstructure in natural and experimentally produced compositionally equivalent crystalline material. The aim of this investigation is to develop a better understanding of the crystallization and emplacement of granitoids. The JCPDS Powder Diffraction File has been implemented on a search/ display system utilizing the full organic-inorganic data base on a CD-ROM drive.

REGIONAL MAPPING PROJECTS

Several members of the Department continue to be active in regional studies. Dr. R.K. Pickerill, in collaboration with Dr. K.L. Currie of the Geological Survey of Canada, and Dr. D. Nance of the University of Ohio, is involved in regional mapping in the Saint John area (New Brunswick). Professor I.M. Patel is working on the Precambrian-Cambrian boundary in New Brunswick. Dr. J.P.A. Noble is continuing his regional stratigraphic studies of the Silurian-Devonian of northern New Brunswick. Acadian cleavage in mainly Siluro-Devonian rocks in southwestern New Brunswick and adjacent Maine is being investigated by Dr. P. Stringer.

Graduate students of Dr. H.W. van de Poll are continuing sedimentological mapping and basin analysis of Carboniferous and Lower Permian strata in eastern Canada. Specific projects around Tatamagouche, Nova Scotia and in southwestern Prince Edward Island by PhD student R.J. Ryan and MSc student C. Place, respectively, are nearing completion.

Postgraduate students working under Dr. P.F. Williams' direction continue mapping in the Dunnage zone around eastern Notre Dame Bay (Newfoundland), in the Meguma terrane, and in the vicinity of Thompson Mine, Manitoba.

SEDIMENTOLOGY

Dr. J.P.A. Noble is continuing his long-range sedimentological studies emphasizing the diagenesis and burial histories of the Silurian-Devonian basins in northern New Brunswick and Gaspé. In particular comparisons of diagenesis in the basins and adjacent shelf borders, is shedding light on the structural and burial histories of these marginal zones. A similar, but much better exposed (and much better known stratigraphically) foreland basin in the Alps, is now being studied for the information it provides on the less well known Appalachian basins.

Professor I.M. Patel is continuing a study of the sedimentology of the early Lower Cambrian, Ratcliffe Brook Formation in southeastern New Brunswick and is attempting correlation with similar sequences in parts of the northern Appalachians and Europe.

Dr. R.K. Pickerill is contributing sedimentological work to a regional study of the Saint John Group, and is continuing his extensive studies of Middle Ordovician sedimentation of the Trenton Group carbonates of Quebec.

In addition to the obvious sedimentological bias of their regional projects mentioned above, Dr. H.W. van de Poll and Professor I.M. Patel are continuing specialized studies on physical diagenesis. These studies concentrate on post depositional processes related to compaction of the sediments. Their findings suggest that many sedimentary features, including grain-matrix and clastic ratios and certain types of sedimentary structures are not the result of primary processes, but are caused by secondary processes of sedimentary remobilization during compaction. This work is ongoing in conjunction with Carboniferous Basin analysis and finds potential applications in facies analysis, paleoseismic interpretations, syndepositional tectonics, and petroleum reservoir studies.

Dr. B.E. Broster continued his joint study with Dr. J.J. Clague of the Geological Survey of Canada, Vancouver, on glaciogenic deformation of soft sediments in northern British Columbia.

STRUCTURAL GEOLOGY

Dr. J.C. White spent the fall-term at Cornell University while on sabbatical leave. Research carried out during this time concentrated on microstructural and microchemical examination of shock deformed anorthosites from Manicouagan, Quebec. Collaborative work with R.L. Barnett on metasomatic feldspars from Hemlo, Ontario has been completed. An ongoing study of deep shear zones has been extended to basal ophiolite shear zones deformed under extreme conditions.

Dr. P.F. Williams and students are working on major faults in Atlantic Canada including the Dover Fault, Newfoundland with Mr. A. Caron, faults in southern New Brunswick with former student Mr. A. Leger, the Chanceport-Lukes Arm Fault system in Newfoundland with Mr. B. LaFrance, and the Indian Islands Faults, Newfoundland with Dr. J. Urai. The objective of these studies is to synthesize Appalachian ductile and brittle faulting history as a basis of understanding amongst other things its influence on Carboniferous sedimentation and emplacement of quartz and calcite veins, many of which are related to the faults.

Dr. P.F. Williams is also continuing his research with Dr. D. Keppie and Mr. S.J. Hwang on the structural implications of shear zones in the Shelburne, Nova Scotia area. In addition, he completed an MDA investigation with Dr. C. Hy on the geological history of gold-bearing veins in Nova Scotia. He is involved in a GSC-funded project at Thompson Mine, Manitoba with Dr. C. van Staal and Mr. W. Bleeker. He has recently begun a GSC-funded project to map parts of the Tavani map area (in the vicinity of Rankin Inlet), Northwest Territories at 1:50 000 scale with emphasis on the stratigraphy, structure, geochemistry, geochronology, and economic potential of the greenstone belts. The project involves post-doctoral fellows A. Park and S. Ralser. Dr. Williams is conducting computer simulation experiments on the development of folds during shear straining.

NEOTECTONICS

Drs. K. Burke and P. Stringer are continuing an investigation of neotectonic features in southwestern New Brunswick under a research agreement with Energy, Mines and Resources Canada. An atlas of maps at a scale of 1:7500 was compiled by Dr. P. Stringer and Mr. C. Hawkes from published maps and reports and unpublished fieldwork. This compilation is being used as a basis for the investigation of NW-trending faults in the region. A 1:50 000 geological map of south-western New Brunswick and eastern Maine showing NW-trending faults is being prepared to examine the possible relationship between fault movement and earthquakes in the region.

Drs. B.E. Broster and K. Burke commenced a joint project in Saint John to examine the neotectonic implications of displaced striae in bedrock. They expect to submit their results for publication toward the end of 1988.

DEFORMATION STUDIES

A group of researchers in the Department of Geology have recently established a Centre for Deformation Studies in the Earth Sciences. The members are linked by their common interest in deformational mechanics of the Earth, its constituent materials, and attendant processes. Present members include Drs. B.E. Broster, K.B.S. Burke, J.G. Spray, P. Stringer, H.W. van de Poll, J.C. White, and P.F. Williams. The membership represents a wide variety of research interests such as, glaciogenic and soft-sediment deformation, earthquake seismology, neotectonics, fault-rock generation, experimental and computer simulations, shear-zone rheology, microstructural analysis and regional mapping. The formation of the centre underlies a commitment to enhance the existing research programs of participants and encourage the development of new fundamental and applied research in deformation studies at the individual and group levels.

SECTION IV

RESEARCH AND PRODUCTIVITY COUNCIL

MINERAL- AND ENERGY-RELATED ACTIVITIES AT THE NEW BRUNSWICK RESEARCH AND PRODUCTIVITY COUNCIL

Staff of the Mineral Development and Processing Department

INTRODUCTION

The Research and Productivity Council (RPC) is a contract research development, demonstration, and service organization serving industry in New Brunswick, Canada, and abroad. Activities are directed at productivity enhancement, process optimization, product innovation, quality control, technology transfer, environmental protection, worker safety, and other tasks for the benefit of industry in manufacturing, natural resource exploitation, and energy matters.

RPC's services to the mineral industry encompass the disciplines of mineralogy/microscopy, mineral processing, hydrometallurgy, pyrometallurgy, analytical chemistry, and fuel technology. Petrologists, mineralogists, mineral processing engineers, metallurgists, chemical engineers, chemists, and physicists offer a wide range of expertise in all of the above-mentioned disciplines.

MINERALOGY

The Mineralogy Section has undertaken studies for many clients. Samples of ore, drill core, and mill products containing gold, silver, copper, lead, zinc, iron, titanium, potassium, and antimony were examined. Other samples examined were aggregates, brick concrete, and metals.

Work has continued on an MDA project to study the mineralogy and geochemistry of New Brunswick's potash deposits. The Supply and Services contract is administered by CANMET. In a second project, related to a now-completed MDA project, RPC is a subcontractor to a company investigating the alkali reactivity of potential aggregate sources. Alkalies and aggregates in concrete react to cause premature failure of concrete structures.

Several projects using the microprobe have been completed for the Geological Surveys Branch of NBDNRE. These data have improved the understanding of the geology of New Brunswick and have contributed to maps and models that can be used by the mining industry to exploit new mineral occurrences. In cooperation with industry, the federal government, and the University of New Brunswick, a new mineral occurrence in the Province has been completely documented.

Examination and data processing are continuing on a project to evaluate the concentrator of Brunswick Mining and Smelting. In this study, samples from the various process streams have been analysed using an electron microprobe interfaced with an automated image analyzer. The percentages of liberated and unliberated chalcopyrite, galena, sphalerite, and pyrite in each stream have been determined and these data have been used to obtain distributions. CANMET's MATBAL 5 computer program for material balance data adjustment was used to calculate the material balances.

Several studies have been undertaken for mining companies to help them better understand the behaviour of minerals in their mills.

PROCESSING

The processing section has undertaken studies in the areas of flotation, hydrometallurgy, pyrometallurgy, and fuel technology.

The technical and economic evaluation of the RPC Sulphation Roast Leach process for the treatment of combined lead-zinc concentrates was completed and the reports submitted to the Management Committee of the Sulphation Roast Leach Pilot Plant Subsidiary Agreement.

The six-inch bubbling fluidized bed roaster and ancillary equipment have been refurbished in preparation for treating refractory gold ore.

Other studies include recovering gold from old tailings; production of copper sulphate from copper matte; dewatering of fine coal; development of an electrochemical method for the prevention of scaling during jarosite precipitation in the zinc refining process; and material balance calculations using CANMET's MATBAL 5 computer program.

A major environmental impact study was carried out at CFB Gagetown. Also, the viability of a plant for the recovery of lead from lead-acid batteries was determined for an industrial client. This plant would be located in northeastern New Brunswick.

FUEL TECHNOLOGY

A comprehensive development program directed toward providing a solution to the acid rain problem associated with burning high sulphur coals from Eastern Canada has been continued. A pilot scale circulating fluidized bed unit was used to study factors governing sulphur capture while burning high sulphur coals with limestone or oil shale sorbents. Results from the study have been used by NB Power in their effort to optimize sulphur capture at the 22 megawatt demonstration circulating fluidized bed in Chatham.

The wood energy program has focused on the implementation of a wood-fired boiler workshop, the harvesting of non-merchantable stands for energy conversion, and an assessment of the economic availability of wood residues in New Brunswick. In other areas, a flotation technique to recover usable fibre from pulp mill knotter rejects was undertaken.

INDUSTRIAL CHEMISTRY AND ANALYTICAL SERVICES

The Industrial Chemistry and Analytical Services Section has carried out a number of mineral-related projects. These have included the analysis of a large number of shale samples; analysis of coal samples; studies of the acid-generating potential of waste rock from a number of complex sulphide ore bodies; analysis of mill samples from various operations; and analysis of fertilizer samples.

An increasing percentage of the problems being handled are environmental. Major projects in this area included a fertilizer spill in the Saint John River, wood preservative chemicals at an industrial site, hazardous waste surveys, and air-quality surveys related to asbestos.